Mississippi State Geological Survey

ALBERT F. CRIDER, DIRECTOR.

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Cement and Portland Cement Materials of Mississippi

By ALBERT F. CRIDER

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STATE GEOLOGICAL COMMISSION.

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LETTER OF TRANSMITTAL.

JACKSON, MISS., July 20, 1907.

To Governor James K. Vardaman, Chairman, and Members of the Geological Commission:

GENTLEMEN—I submit herewith my report on Cement and Portland Cement Materials of Mississippi.

Very respectfully,

ALBERT F. CRIDER,

Director.

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In the discussion of the technology and manufacture of cements the various works of Mr. E. C. Eckel, of the United States Geological Survey, have been freely used.

CEMENT AND PORTLAND CEMENT MATERIALS OF MISSISSIPPI.

By Albert F. Crider.

INTRODUCTION.

The growth of almost every line of the mining industry in America in the last decade has been most phenomenal. The mineral production of the United States for 1905, the latest year for which complete official returns are available, was $1,623,877,120. Of this amount $921,024,019 was contributed by the non-metallics, and $702,453,101 by the metallics.

The value of Portland cement products is surpassed only by iron, gold, copper, coal, oil and stone. In its importance to the advancement of the present civilization it is surpassed only by iron, coal and oil. Its per cent of increase in production and consumption since 1890 is greater than any mineral mined in the United States.

Until 1905 the amount of Portland cement imported into the United States was greater than the amount exported. In 1891 the amount of production was 454,813 barrels, and the amount imported was 2,998,313 barrels. In 1905 the amount imported had been reduced to 896,845 barrels, and the amount exported was 897,686 barrels.

Some sections of the United States have not been able to secure all the cement they could use, and there is an increasing demand for our cement in foreign countries, especially in the Central and South American States, and the West Indies. But before we need to exploit fields outside of the United States for our cement we must create a surplus over and above the amount consumed at home. But with the increase in production due to the erection of new plants and the enlargement of the old ones comes new demands for cement as a structural material from every section of the country.

No section of the United States is advancing quite so rapidly as the South. The advance in the manufacture of cements has not kept

pace with the progress in other lines of industry, and for this reason the South offers practically an open field to the cement manufacturer. And in no section of the South is this more evident than in Mississippi where, at present, there is not a single cement plant. The object of this report is to point out the geographical distribution, the available amount and the quality of cement materials, and call attention to the economic advantages offered for the erection of cement plants within the State.

EARLY HISTORY OF THE PORTLAND CEMENT INDUSTRY.

Portland cement was first made in 1824 by Joseph Aspdin, a bricklayer in Leeds, England. The name "Portland" was chosen because of the resemblance of the cement to the oolitic limestone of Portland, England. The limestone is extensively used in England as a road metal and building stone.

The first cement was made by taking a specific quantity of road scrapings from roads repaired with the oolitic limestone and reduced to a powder and calcined. The calcined material was then combined with a specific quantity of argillaceous earth or clay, mixed with water, and the mixture placed in a pan and heated until all the water was evaporated. After this the mixture was broken into small lumps and calcined in a furnace similar to a lime kiln till the carbonic acid was entirely expelled. It was then cooled and reduced to a powder which had the power of setting when mixed with water.

Aspdin's original patent did not specify the percentages of limestone and clay in the mixture, and he also omitted to state that the mixture should be burned until incipient vitrification is attained. In the absence of machinery for grinding the hard limestone, he was forced to calcine it before it was mixed with the clay.

From this crude beginning has developed one of the greatest industries of building material of modern times.

PRESENT CONDITION OF THE INDUSTRY IN THE UNITED STATES.

The Portland cement industry has had a more marvelous growth than any other large industry of this era. It came at a most opportune time in the development of the country. It has prolonged the

life of lumber and supplemented iron and steel. It has become one of the leading and most substantial products for general construction work where strength, durability and economy are required. It is used alone, or as a reinforcement in the construction of bridges, business and dwelling houses, aqueducts, sewers, pavements, large foundation walls and dikes such as the Galveston wall, docks, wharves and levee work; besides in many minor ways, such as in making fence posts, telegraph poles, railway ties, monuments, and in various other lines of construction work.

The output of Portland cement in the United States in 1890 was only 335,500 barrels. In 1900 it had reached 8,482,020. The most rapid growth of the industry was between 1900 and 1905. Preliminary figures in 1906, announced by the United States Geological Survey, show that 46,463,424 barrels were produced, valued at $52,446,186. This is even a greater increase in output and in value than that of the previous year.

The following table shows the amount and value of Portland cement produced in the different States where this article was manufactured in 1903, 1904 and 1905:

TABLE 1.

PRODUCTION OF PORTLAND CEMENT IN THE UNITED STATES IN 1903, 1904 AND 1905, BY STATES.†

[BARRELS.]

STATE.	1903.			1904.			1905.		
	Number of works	*Quantity.*	*Value.*	*Number of works*	*Quantity.*	*Value*	*Number of works*	*Quantity*	*Value*
Alabama (*a*)	1	....	....	1	....	....	1	....	....
Arkansas*	1	....	....	1	....	....	1	....	....
California	3	631,151	$1,019,352	3	1,014,558	$1,446,909	3	1,225,429	$1,671,816
Colorado	1	258,773	436,535	1	490,294	638,167	1	786,232	1,172,027
Georgia (*a*)	1	....	....	1	....	....	1	....	....
Illinois	5	1,257,500	1,914,500	5	1,326,794	1,449,114	5	1,545,500	1,741,150
Indiana	3	1,077,137	1,347,797	4	1,350,714	1,232,071	6	3,127,042	3,134,219
Kansas	1	1,019,682	1,285,310	2	2,643,939	2,134,612	4	....	....
Kentucky (*b*)	....	....	....	1	....	....	1	....	....
Michigan	13	1,955,183	2,674,780	16	2,247,160	2,365,656	16	2,773,283	2,921,507
Missouri (*b*)	2	825,257	1,164,834	2	....	....	2	3,879,542	4,164,974
New Jersey	3	2,693,381	2,944,604	3	2,799,419	2,099,564	3	3,654,777	2,775,768
New York	11	1,602,946	2,031,310	11	1,362,514	1,257,561	11	2,111,411	2,044,253
Ohio	8	729,519	998,300	7	910,297	987,899	8	1,312,977	1,390,481
Pennsylvania	17	9,754,313	11,205,892	17	11,496,099	8,969,206	18	13,813,487	11,195,940
South Dakota (*c*)	1	....	....	1	....	....	1	....	....
Texas (*c*)	2	....	....	2	....	....	3	....	....
Utah (*c*)	1	....	....	1	....	....	1	....	....
Virginia	1	538,131	690,105	1	864,093	774,360	1	1,017,132	1,033,732
Washington	....	....	....	....	....	....	1	....	....
West Virginia (*a*)	1	....	....	1	....	....	1	....	....
Total	76	22,342,973	$27,713,319	81	26,505,881	$23,355,119	89	35,246,812	$33,245,867

†Mineral Resources of the United States, 1905, U. S. Geological Survey, p. 926. *Shut down.

(*a*) Total amount combined and given with Virginia.

(*b*) Total amount combined and given with Kansas.

(*c*) Total amount combined and given with Colorado.

New plants are reported to be in process of construction or completed in the following States:

Iowa, 2 plants.
Oregon, 1 plant.
Wisconsin, 2 plants.
Tennessee, 1 plant.
Alabama, 2 plants.
Georgia, 1 plant.

The total number of Portland cement plants in the United States at the present time approaches the one hundred mark.

CEMENT INDUSTRY IN THE SOUTH.

Of the whole number of plants in the United States there are but 8 in the South producing cement, and about 4 new plants under construction. According to the latest official report the South produces less than 4 per cent of the total amount of Portland cement manufactured in the United States. This, added to the fact that the South is growing more rapidly than any other section of the country, gives a promising outlook for the development of the cement industry. There should be a large number of plants located in various sections of the South to equalize the output in the United States; at least a sufficient number to supply the local demands.

At present Mississippi is dependent upon the cement plants of Alabama and other States for cement. There is a wide field in Mississippi for the development of this important industry. With an abundance of excellent raw materials favorably located, as at Vicksburg where coal is cheap and with railway and water transportation, there is no reason why Mississippi should not enter the field as a cement-producing State and supply a large amount of the increasing demand in the middle South. The erection of a plant in this undeveloped territory would be a paying investment, and would ultimately cheapen the product to the consumers.

It has been reported by government authorities that the construction of some of the locks of the Panama Canal will require about 92,000 carloads of cement. This amount equals about one-fourth of the output of all the cement plants in the United States for 1905. There is an ever increasing demand for cement in the United States as shown

by the fact that during 1905 over 35,000,000 barrels were used, besides 896,845 barrels shipped in from other countries. While the Panama Canal trade may appeal to some of the factories of the United States, there is not a sufficient number of plants in the South at the present time to supply the increasing local demand.

CLASSIFICATION OF CEMENTS.*

Cements may be classified under two general heads, Simple cements and Complex cements.

SIMPLE CEMENTS.

Simple cements are those in which the setting properties are similar to the original raw material. Under this class come (1) hydrate cements and (2) carbonate cements.

(1) *Hydrate Cements.*—Hydrate cements include those cements in which the water of combination from certain rocks has been driven off by heat not exceeding a temperature of 400° Fahrenheit, and which upon the reabsorption of water produce an artificial rock similar to the original.

The hydrate cements are "Plaster of Paris," "Keene's cement," "Parian cement" and "Cement plaster." They are all manufactured from gypsum and differ from each other only in the addition of relatively small amounts of clay, limestone, sand and other materials; or by slight variations in the methods of manufacture.

(2) *Carbonate Cements.*—Carbonate cements are formed from limestone by dissociating and driving off the carbon dioxide (CO_2) and the water of combination by the application of heat at a temperature between 1,382° F. and 1,652° F., leaving behind "quicklime" or unslaked lime (CaO). "Quicklime" on being treated with water expands and gives off heat, forming the hydrated calcium oxide or slaked lime ($Ca\ H_2O$).

The cementing qualities are imparted to the hydrated calcium oxide on the reabsorption of carbon dioxide from the air, forming the original calcium carbonate or limestone. Only the outer portions of the walls are thoroughly recarbonated, since the reabsorption of the carbon dioxide can only take place where the material is exposed

*In the treatment of this subject the writer has followed E. C. Eckel in Limes, Cements and Plasters.

to the air. The products of carbonate cements are calcium and magnesian limes. It requires a higher degree of temperature to dissociate a relatively pure limestone than one containing a high per cent of magnesium, and the resulting quicklime slakes more readily and has a quicker set. The magnesian limes have a slower set, but attain a higher degree of strength.

COMPLEX CEMENTS.

In the manufacture or in the use of complex cements certain chemical changes take place forming new compounds which impart the setting properties to the cement. In this class come natural cements, Puzzolan cements, hydraulic limes, and Portland cement. In all of these the cementing quality is imparted by calcium oxide in the presence of silica and alumina approaching a tri-calcic silicate. There are, however, certain natural or added impurities in the limestone and clays or shales to form various lime silicates and silico-aluminates. The most common impurities formed in limestones, clays and shales are iron, magnesia, alkalies and sulphur. Calcium sulphate is added to some cements to retard the set. The impurities act as a flux upon the body of the materials and greatly reduce the temperature of incipient fusion.

Natural Cement.

Natural cement is produced by burning an impure limestone containing from 15 to 40 per cent of silica, alumina and iron oxide. In addition to these ingredients it usually contains a small per cent of alkalies, sulphur trioxide and water.

The temperature required for burning hydraulic limestone is about the same as that obtained in burning lime, or between 900° to 1,300° F. All the combined water and most of the carbon dioxide are driven off and the lime and magnesia combine with the iron oxide, silica and alumina. The fluxing properties, such as soda and potassium, aid in decomposing these ingredients. The burned product shows little or no free lime.

The burned mass or clinker is ground to a fine powder, which has the power of setting when placed under water.

Natural cements differ from common lime in possessing hydraulic properties and refusing to slake before grinding. They differ from

Portland cements in not being a mechanical mixture of raw materials possessing definite chemical constituents. They have a specific gravity which ranges from 2.7 to 2.9; while Portland cement has a specific gravity from 3.0 to 3.2. Natural cements are burned at a lower temperature, have a quicker set, and a much lower ultimate strength than the true Portland cements.

Magnesia is found in comparatively large quantities in the raw materials used in the natural cement plants in the United States. It does not, however, possess any hydraulic properties within itself, and could be easily exchanged for lime without affecting the quality of the cement. The hydraulic properties are imparted to the limestone by the clayey materials, the silica, and the iron oxide.

The following are analyses of natural cement rock now in use in American and European natural cement plants:

TABLE 2.

ANALYSES OF NATURAL CEMENT ROCK USED IN AMERICAN AND EUROPEAN PLANTS.*

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	H_2O	S
Rosendale, N. Y.	10.90	3.40	2.28	29.57	14.04	0.61	37.90	n.d.	n.d.
Milton, N. D.	14.00	6.70		37.60	n.d.	0.58	n.d.	n.d.	1.45
Defiance, Ohio	42.00	7.00	7.10	9.91	5.81	n.d.	14.18	14.00	......
Copley, Pa.	18.34	7.49		37.60	1.38	n.d.	31.06	3.94	......
Balcony Falls, Va.	17.38	7.80		34.23	9.51	n.d.	30.40	n.d.	n.d.
Milwaukee, Wis.	17.00	4.25	1.25	24.64	11.90	n.d.	32.46	n.d.	......
Mankato, Minn.†	16.00	5.85	2.73	22.40	14.99	n.d.	34.11	n.d.	n.d.
Fort Scott, Kan.	17.26	2.05	5.45	34.45	5.28	n.d.	32.87	n.d.	n.d.
Utica, Ill.	17.01	3.35	2.39	32.85	8.45	1.81	34.12		......
Louisville, Ky.	9.80	2.03	1.40	29.40	16.70	n.d.	41.49	n.d.	n.d.
Belgium	15.75	3.95	1.00	43.10	0.49	0.50	35.21		n.d.
England	18.00	6.60	3.70	39.64	0.10	n.d.	29.46	1.30	n.d.

Puzzolan Cement.

The process of making Puzzolan cement was known to the ancients, and was named from its use at Puzzolano, Italy.

It is produced from an uncalcined mixture of slaked lime and a silico-aluminous material, such as volcanic ash, or blast-furnace slag. The process is simply a mechanical mixture of the two materials.

*Cements, Limes and Plasters, E. C. Eckel, 1905, pp. 204–217.
†Alkalies 0.76.

The ingredients are thoroughly mixed and ground to a fine powder, which will set under water. The per cent of lime and slag used in the mixture is about 35 parts of slaked lime to 100 parts of slag. Puzzolan cements are of a lighter color, have a lower specific gravity and a much lower set than Portland cements.

Portland Cement.

There are at present many different kinds of cements manufactured and sold as Portland cements. Some of these are made by burning a natural magnesian, argillaceous limestone and grinding it to a powder. According to the best authorities, however, on the manufacture of cements, these would be excluded from the list of true Portlands. The following definition,* perhaps, comes near fulfilling all the conditions of the best Portland cements:

"By the term Portland cement, is to be understood the product obtained by finely pulverizing clinker produced by burning to semi-fusion an intimate artificial mixture of finely ground calcareous and argillaceous materials, this mixture consisting approximately of three parts of lime carbonate (or an equivalent amount of lime oxide) to one part of silica, alumina, and iron oxide. The ratio of lime (CaO) in the cement to the silica, alumina, and iron oxide together shall not be less than 1.6 to 1, or more than 2.3 to 1."

From the above definition it is evident that all cements produced by burning argillaceous limestones without grinding the mixture before burning are excluded from the list of true Portland cements.

To burn the materials to a semi-fused mass requires a temperature of something like 3,000° F. This can only be obtained in kilns made especially for this purpose.

The chemical changes which take place in the kiln are, first, the expulsion of the mechanically held water, which is driven off at a temperature of 212° F.; second, the dissociation of the lime carbonate at about 1,300° F., setting free carbon dioxide and sulphur trioxide third, at about 2,600° F. and above, clinkering takes place, the silica and alumina are decomposed, and the lime oxide, silica, alumina and iron oxide combine, forming silicates, aluminates and ferrites of lime in definite proportions.

*Cements, Limes and Plasters, E. C. Eckel, p. 297.

The semi-fused mass when finely pulverized will set under water. The specific gravity of Portland cement is from 3.0 to 3.2.

The chemical composition of Portland cement varies within certain limits. The first Portlands manufactured in England were low in lime oxide. Some of the earliest brands ran as low as 50 per cent in lime. The best brands now manufactured in the United States have a general average of about 62 per cent of lime oxide. In an investigation of 81 analyses of American brands, the maximum amount of lime oxide was about 65.44 per cent, and the minimum amount 58.07 per cent. The amount of silica varied from about 19 per cent to 24 per cent, with a general average of about 21.75 per cent. The amount of alumina and iron oxide together varied from 6 per cent to 13.5 per cent with a general average of about 10.5 per cent. The amount of magnesia varied from a trace to 3.5 per cent. The greatest amount of alkalies was 2.25 per cent. The amount of sulphur trioxide varied from a fraction of 1 per cent to 2.786 per cent.

TABLE 3.

ANALYSES OF AMERICAN PORTLAND CEMENTS.*

	1	2	3	4	5	6	7	8	9	10	11	12
Silica (SiO_2)	20.14	22.48	20.80	22.04	21.20	19.92	21.96	22.00	22.00	22.50	20.25	24.00
Alumina (Al_2O_3)	7.51	6.52	7.39	6.45	6.05	9.83	9.29	9.74	7.74	8.35	13.44	7.50
Iron oxide (Fe_2O_3)	3.33	4.46	2.61	3.41	3.33	2.63	2.67		4.61	4.25		2.40
Lime oxide (CaO)	62.71	62.93	64.00	60.92	58.07	60.32	60.52	62.34	59.50	62.35	63.60	62 00
Magnesia (MgO)	2.34	1.48	n.d.	3.53	2.80	3.12	3.43	2.54	0.90	.....	1.03	2.50
Alkalies (K_2O, Na_2O)	.....	.....	.....	.....	2.20	.....	.....	.....	1.20	.....	.....	.....
Sulphur trioxide (SO_3)	1.64	1.30	n.d.	2.73	...	1.13	1.49	1.40	0.80	1.75	0.41	1.50

1. Edison Portland Cement Co., New Jersey.
2. Catskill Portland Cement Co., New York.
3. Empire Portland Cement Co., New York.
4. Empire Portland Cement Co., New York.
5. Buckeye Portland Cement Co., Ohio.
6. American Portland Cement Co., Pennsylvania.
7. Atlas Portland Cement Co., Pennsylvania.
8. Lehigh Portland Cement Co., Pennsylvania.
9. Western Portland Cement Co., South Dakota.
10. Texas Portland Cement Co., Texas.
11. Alabama Portland Cement Co., Alabama.
12. Michigan Portland Cement Co., Michigan.

*Cements, Limes and Plasters, E. C. Eckel, 1905, pp. 577 to 579.

RAW MATERIALS OF PORTLAND CEMENT.

The principal constituents which enter into the manufacture of Portland cement are lime, silica, alumina and iron oxide. These materials are found widespread in nature and occur in various combinations, especially in sedimentary rocks. It is from these rocks the necessary constituents are found for making Portland and natural cements. Lime is found in argillaceous limestones, hard pure limestones, chalks, marls, oyster shells, alkali waste and blast-furnace slags. Silica, alumina and iron oxide are found principally in clays, shales and slates, although they all frequently occur in greater or less quantities in limestones. A limestone may vary in composition from pure calcium carbonate ($CaCO_3$), calcite, to a rock containing an increasing amount of clay or sand, until the name limestone is no longer applicable. There is a regular gradation from a pure limestone to a pure clay or sand. It is possible, therefore, to find a rock in nature, in small quantities at least, which would contain the exact proportions of lime, silica, alumina and iron oxide for a Portland cement. It is hardly probable, however, that such a rock would occur in large quantities.

ARGILLACEOUS LIMESTONE.

A limestone containing a relatively large amount of clayey material in chemical combination with lime is called an argillaceous limestone. It has been formed at the bottom of an open or inland sea by calcareous remains of small invertebrate organisms, in the presence of sediments carried by streams from the shore. The purest limestones are formed at too great a distance from the shore to receive any accumulation of sediments. Owing to the constant agitation of the water near the shore sandstones and clays have but little or no organic remains. The argillaceous limestones, therefore, represent an intermediate stage between the pure limestones and the non-calcareous near-shore deposits.

There is no definite rule for determining when a limestone shall be called "argillaceous." The argillaceous limestone in the "Lehigh district" of Pennsylvania and New Jersey has been called "cement rock," because it has been the most important source of cement in this country. Until as late as 1903 two-thirds of the Portland cement

manufactured in the United States was made from the "cement rock" of the Lehigh district, mixed with pure limestone. This district is still producing 38 per cent of the Portland cement of the United States.

The quality and composition of some of the argillaceous limestones now used by American cement plants are here given:

TABLE 4.

ANALYSES OF ARGILLACEOUS HARD LIMESTONES, "CEMENT ROCK," LEHIGH DISTRICT.*

<table>
<tr><td>Silica (SiO_2)</td><td>18.30</td><td>15.97</td><td>17.32</td><td>19.62</td><td>16.77</td><td>15.73</td><td>19.06</td></tr>
<tr><td>Alumina (Al_2O_3)</td><td>6.11</td><td>7.53</td><td rowspan="2">9.11</td><td rowspan="2">5.68</td><td rowspan="2">6.50</td><td rowspan="2">7.92</td><td>4.44</td></tr>
<tr><td>Iron oxide (Fe_2O_3)</td><td>1.85</td><td>2.24</td><td>1.14</td></tr>
<tr><td>Lime carbonate ($CaCO_3$)</td><td>36.38</td><td>34.34</td><td>38.59</td><td>39.08</td><td>41.37</td><td>39.62</td><td>38.77</td></tr>
<tr><td>Magnesium carbonate ($MgCO_3$)</td><td>2.13</td><td>3.93</td><td>2.05</td><td>2.35</td><td>n.d.</td><td>1.81</td><td>2.02</td></tr>
<tr><td>Carbon dioxide (CO_2)</td><td>28.96</td><td>32.80</td><td>32.55</td><td>33.25</td><td>n.d.</td><td>33.08</td><td>32.66</td></tr>
</table>

ANALYSES OF ARGILLACEOUS LIMESTONES FROM WESTERN UNITED STATES.†

Silica (SiO_2)	21.02	6.80	20.06	7.12	14.20
Alumina (Al_2O_3)	8.00	3.00	10.07	2.36	5.21
Iron oxide (Fe_2O_3)	.....	.....	3.39	1.16	1.73
Lime carbonate ($CaCO_3$)	62.08	89.80	63.40	87.70	75.10
Magnesium carbonate ($MgCO_3$)	3.80	0.76	1.54	0.84	1.10

It will be seen by a study of the above analyses that in order to bring the argillaceous limestones to the proper composition of Portland cement (75 to 77 per cent of lime carbonate) they require the addition of a purer limestone.

HARD PURE LIMESTONE.

Pure limestone has the composition of calcite ($CaCo_3$), corresponding to the composition, calcium oxide, 56 per cent; carbon dioxide, 44 per cent. The theoretically pure limestone is rarely met with in nature in large quantities. The most common impurities found in limestones are magnesia, silica, alumina, iron, alkalies and a few minor materials.

Magnesia may be carried in solution and introduced into the limestone when it is being formed, or subsequently forming a mag-

*Cements, Limes and Plasters, E. C. Eckel, 1905, p. 329.

†Bulletin 243 U. S. Geological Survey, 1905, p. 32.

nesian limestone. The calcium carbonate is replaced by the magnesium carbonate. Limestones in which the calcium carbonate and the magnesium carbonate are united in equal molecular proportions are called dolomites, having a formula $CaCO_3$, $MgCO_3$, and are composed of 54.35 per cent calcium carbonate, and 45.65 per cent magnesium carbonate. Magnesia in Portland cement is an inert material and limestones containing more than 5 or 6 per cent of it should be avoided.

Where the impurities in the limestones are chiefly clayey materials, silica, alumina and iron oxide, the chemical composition of the raw material is of the greatest importance to the cement manufacturer, and should be carefully studied. Where the silica is present in limestones in the form of free sand or chert nodules it will not easily enter into combination with the calcium carbonate, and is, therefore, largely an inert material. If, however, silica and alumina are combined in the form of clay, shale or slate they readily combine with the calcium carbonate under the action of heat.

A cement manufacturer having a limestone with a high per cent of calcium carbonate must select a clay with a high silica-alumina ratio. If, however, he has a limestone with a low per cent of calcium carbonate great care must be used in selecting a clay with a low silica-alumina ratio.

"For this reason it may be taken as a safe rule that when a limestone carries less than 90 per cent of lime carbonate it should give a value between 2.25 and 3.00 for the ratio $\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$. These are comfortable limits, and will give the manufacturer considerable latitude in his choice of a clay to mix with it."*

CHALK.

Chalk is a white limestone so soft that it can be easily scratched with the finger nail. Where pure it is composed of fine sediment of calcium carbonate derived chiefly from shells of foraminifera. Like other forms of calcareous deposits it varies from a rather pure calcium carbonate to a chalky limestone containing silica, alumina, magnesia, iron and other impurities, requiring little additional material to make

*Cements, Limes and Plasters, E. C. Eckel, 1906, p. 315.

it suitable for Portland cement manufacture. The range in composition of chalky limestones used in American cement plants is here given:

TABLE 5.

ANALYSES OF CHALK USED IN AMERICAN CEMENT PLANTS.

<table>
<tr><td>Silica (SiO_2)</td><td>12.50</td><td>9.88</td><td>5.33</td><td>12.13</td><td>2.22</td></tr>
<tr><td>Alumina (Al_2O_3)</td><td rowspan="2">2.76</td><td rowspan="2">6.20</td><td rowspan="2">3.03</td><td>4.17</td><td>.92</td></tr>
<tr><td>Iron oxide (Fe_2O_3)</td><td>3.28</td><td>.18</td></tr>
<tr><td>Lime (CaO)</td><td>45.20</td><td>43.19</td><td>50.53</td><td>42.04</td><td>54.08</td></tr>
<tr><td>Magnesia (MgO)</td><td>0.50</td><td>0.52</td><td>0.55</td><td>0.44</td><td>0.10</td></tr>
<tr><td>Carbon dioxide (CO_2)</td><td>36.06</td><td>34.49</td><td>50.30</td><td>33.51</td><td rowspan="2">42.50</td></tr>
<tr><td>Water</td><td>1.36</td><td>5.72</td><td>n.d.</td><td>n.d.</td></tr>
</table>

The most extensive calcareous formation in Mississippi is the Selma chalk or "rotten limestone" which is more than 900 feet thick in Lowndes, Noxubee, Oktibbeha, Clay, Monroe and Chickasaw counties, and thins to about 300 feet in Alcorn County. Under the discussion of the Selma chalk are numerous analyses, some of which are inferior to and some better than the ones given above.

FRESH-WATER MARL.

Marl, such as is used in cement manufacture, is a chemical deposit of almost pure carbonate of lime which has been deposited in inland seas and lakes by streams or springs carrying lime carbonate in solution. Marls differ from hard limestones in that they are masses of granular, incoherent deposits containing land shells and shell fragments.

Workable deposits of marl are chiefly confined to that part of the United States which was formerly covered by glacial deposits. Most of the lakes of northern United States and Canada are due to the damming of streams, and to the uneven distribution of the glacial deposits. The streams of that region carry a large per cent of lime carbonate in solution and deposit it on the sides and bottoms of the enclosed lakes. These marl deposits are still in process of formation.

Marl is in composition, as shown by the following analyses, a comparatively pure lime carbonate, and is correspondingly low in silica, alumina and other impurities. Where used in cement manufacture it requires the addition of a large amount of clay to bring it to the proper mixture.

TABLE 6.

ANALYSES OF MARLS USED IN AMERICAN CEMENT PLANTS.*

Silica (SiO_2)	1.74	1.78	0.19	0.06	1.19
Alumina (Al_2O_3)	0.90	1.21	0.05	0.80	0.55
Iron oxide (Fe_2O_3)	0.28		0.07		0.25
Lime (CaO)	49.84	49.55	51.31	55.00	52.50
Magnesia (MgO)	1.75	1.30	1.93	.....	1.16
Alkalies (K_2O_3, Na_2O)	.....	.....	.....	.....	1.84
Sulphur trioxide (SO_3)	1.12	1.58	0.14	0.05	tr.
Carbon dioxide (CO_2)	46.01	40.35	42.40	43.22	42.51
Organic matter		4.23	2.25	.....	n.d.

OYSTER SHELLS.

Oyster shells are composed almost entirely of lime carbonate, and as such they could be used in the manufacture of Portland cement. At present, however, they are not so used by any plant in the United States.

In regions where oyster canning is carried on extensively oyster shells form an important waste product which is usually disposed of for making shell roads. Where suitable clay can be obtained they might form an important source of Portland cement material.

The oyster shells from Biloxi, Mississippi, as shown by the following analysis, could be used in the manufacture of Portland cement. Good clay can be obtained on Tchouticabouff River.

TABLE 7.

ANALYSIS OF OYSTER SHELLS FROM BILOXI.

Silica (SiO_2)	5.30
Alumina (Al_2O_3)	.73
Iron oxide (Fe_2O_3)	.57
Lime (CaO)	50.25
Magnesia (MgO)	.45
Sulphur trioxide (SO_3)	.25
Volatile matter (CO_2)	41.39
Moisture	.60

ALKALI WASTE.

In the manufacture of caustic soda there is a large per cent of waste material in the form of lime carbonate which is sufficiently pure for use as a Portland cement material.

The possibility of using the waste product depends on the process used in the alkali plant. In the Leblanc process pyrite is used,

*Cements, Limes and Plasters, E. C. Eckel, 1905, p. 342.

which combines with the lime and forms a large percentage of lime sulphide which renders the resulting waste unfit for use in Portland cement manufacture. In the ammonia process of making caustic soda pyrite is not used and the precipitated waste is largely a mass of lime carbonate. The amount of sulphur, magnesia and other impurities found in the waste depends largely on the character of the limestone used. Where a pure limestone is used the waste forms a cheap source of lime for Portland cement.

The following analyses were made from the waste obtained at alkali plants using the ammonia process:

TABLE 8.

ANALYSES OF ALKALI WASTE.*

Silica (SiO_2)	0.60	1.75	1.98	0.98
Alumina (Al_2O_3)	3.04	0.61	1.41	1.62
Iron oxide (Fe_2O_3)			1.38	
Lime (CaO)	53.33	50.60	48.29	50.40
Magnesia (MgO)	0.48	5.35	1.51	4.97
Alkalies (K_2O, Na_2O)	0.20	0.64	0.64	0.50
Sulphur trioxide (SO_3)	n.d.	n.d.	1.26	n.d.
Sulphur (S)	n.d.	0.10	n.d.	0.06
Carbon dioxide (CO_2)	42.43	41.70	39.60	n.d.
Water and organic matter	n.d.		3.80	n.d.

SLAG.

Slag is a by-product obtained from blast furnaces. In refining metallic ores, especially iron, limestone is most commonly used as a flux. In heating the gangue the lime unites with the silica, the alumina and other materials present in the gangue forming fusible silicates. In the high heat to which it is subjected the limestone gives up a large per cent of lime carbonate which in the slag is changed to the oxide. Slags generally contain from 30 to 40 per cent of lime oxide. Dolomite and highly magnesian limestones render the slag unfit for cement manufacture.

Where slag of the proper composition can be obtained in sufficient quantities it may be combined with a pure limestone in the manufacture of Portland cement.

TABLE 9.

ANALYSIS OF SLAG USED IN GERMAN PORTLAND CEMENT PLANTS.*

	Per cent
Silica (SiO_2)	30 to 35
Alumina (Al_2O_3)	10 to 14
Iron oxide (FeO)	00.2 to 01.2
Lime (CaO)	46 to 49
Magnesia (MgO)	00.5 to 03.5
Sulphur trioxide (SO_3)	00.2 to 00.6

*Bulletin 243, U. S. Geological Survey, E. C. Eckel, 1905, p. 37.

*Bulletin 243, U. S. Geological Survey, 1905, p. 38.

CLAY.

Clays have in their composition alumina and silica with impurities of iron, magnesium, sulphur, alkalies and other minor impurities. The proportion of these ingredients varies from the hydrous silicate of alumina, kaolinite, to the lean sandy clays with barely enough alumina in them to bond them.

The value of a clay for use in the manufacture of Portland cement depends on its comparative freedom from impurities. The best clays are those having a greasy, unctuous feel and free from sand. Some clays like those found in the Lafayette formation contain a high per cent of free silica which is not in chemical combination with iron, alumina or lime, and should, therefore, be avoided. Such clays may be well suited for common brick, but ill suited for making cement. A clay which is free from all impurities is hard to find in nature. Residual and transported clays, such as occur in association with the limestones of Mississippi, are apt to contain a large amount of insoluble material, which is inert in the kiln. The purest clays in the State are those found in the Cretaceous and Tertiary formations.

Fortunately for the cement manufacturer clays with a low percentage of impurities may be used. A study of a large number of analyses of clays now used in American cement plants shows a general average of about 61 per cent of silica, the lowest not below 53 per cent, and the highest not above 75 per cent. "The alumina* and iron oxide together should not amount to more than one-half the percentage of silica, and the composition will usually be better the nearer the ratio $Al_2O_2 + Fe_2O_3 = \frac{SiO_2}{3}$ is approached."

The average amount of magnesia in 87 analyses of clays and shales now used in American cement plants is 2.21 per cent. Alkalies and iron pyrite should be as low as possible.

SHALE.

Shale is a product resulting from a mixture of residual materials derived from the decay of all kinds of rocks which have been disintegrated by mechanical and chemical agencies, carried off and deposited by streams along their channels and at their mouths, and

*Cements, Limes and Plasters, E. C. Eckel p. 354

subsequently hardened by rock pressure. The chemical composition of shale is essentially silica and alumina, while iron oxide, lime, magnesia, sulphur and alkalies are of frequent occurrence.

SLATE.

Slates are shales and clays which have been formed by lateral compression developing cleavage planes which may or may not be parallel to the planes of deposition.

Clays, shales and slates may be used in the manufacture of Portland cement. Slates require more power to pulverize them and are, for that reason, less used than clays and shales. As a waste product in slate quarries slate can be obtained very cheaply, and where limestone is accessible it would form a desirable material in Portland cement mixture.

METHODS OF PORTLAND CEMENT MANUFACTURE.

The methods of Portland cement manufacture have been greatly improved in the United States in the last decade. Heavy machinery must be installed for crushing the raw materials to an impalpable flour. The enormous cost of erecting a cement plant is largely attributable to the heavy machinery and the fireproof kilns.

The processes involved in the manufacture of Portland cement may be divided as follows:

Preparing and grinding the raw materials.

Burning.

Grinding the clinker.

PREPARING AND GRINDING THE RAW MATERIALS.

One of the essential differences between Portland cement and natural cement is in the preparation of the mixture before burning. The raw materials for a true Portland are intimately mixed in definite chemical proportions and thoroughly ground before burning. In natural cement the stone is burned as it comes from the quarry, without previously being ground and mixed. The chemical proportions in a Portland cement can, therefore, the more easily be kept within certain narrow limits.

Dry Process.

In the dry method of preparing the mixture for the kiln it is necessary to drive off the mechanically held water from the raw materials. The amount of water contained in the raw materials depends upon the character of the rocks and the condition of the weather.

All freshly quarried limestones contain more or less hydroscopic or mechanically held water in addition to the chemically combined water. Very compact limestones, such as the oolitic limestones of Tishomingo County, carry from ½ to 3 and possibly 4 per cent of water in rainy seasons.

The percentage of water in porous chalky limestones, such as the Selma chalk, will, doubtless, in rainy seasons, run as high as from 10 to 15 per cent. The amount of water in chalks will vary in different geological formations, and in different parts of the same formation.

Clays and shales are more porous than limestones, and hence carry a greater percentage of water. The amount of water carried will depend on the region, the season, the natural drainage, and the porosity of the material. It has been estimated that the total amount of hydroscopic and chemically combined water in clays may range from 6 to 42 per cent.

Where the raw materials are to be finely ground the mechanically combined or hydroscopic water is first removed by some method of drying. In some plants the clays or shales are dried by storing the materials in large sheds. This, however, requires extra shed room, and likewise, additional handling. In most plants it has been found more economical and quicker to dry the raw materials by artificial heat. The materials are usually partially reduced before drying.

Before the introduction of the rotary kiln the materials were dried in drying tunnels and on drying floors.

The most economical and efficient dryer now in use at the large Portland cement plants of the United States is some type of the rotary dryer, constructed in a manner similar to the rotary kilns. At one plant an ordinary rotary kiln is used for drying the raw materials.

In the rotary dryer the materials are introduced into the upper end of the dryer by means of a chute. The combined rotary motion

imparted to the dryer and the action of gravity gradually move the materials to the lower end where they fall on an endless belt and are conveyed to the crushers. In passing through the dryer the materials come in contact with heat and are thoroughly dried.

Dry heat is forced into the dryer at the lower end and moves in an opposite direction to the motion of the raw materials. It thus completely envelopes the raw materials and drives off the water of moisture which partially saturates the dry air.

At the Edison Portland cement plant of New Jersey, a vertical tower-dryer is used for drying the argillaceous and pure limestones used for making cement. The crushed rock is conveyed to the top of the stack, and by means of the baffle system of screens, which partially retard the speed of the fall, descends through the rising gases of combustion, and is thoroughly dried. The dryer has a capacity of 3,000 tons per day, the same as the crusher plant. A piece of rock will pass through the dryer in 26 seconds, reducing the percentage of moisture from 3 or 4 per cent to about 1 per cent. The raw materials are conveyed from the dryer to the crushers and reduced and mixed preparatory to burning. The mixing may be accomplished either before or after grinding. The coarse materials are first crushed in a Gate's crusher, Blake's crusher, or in rolls. All of these mills, working upon different principles, reduce the materials so they that can be handled by Huntingdon, or Griffin mills, comminuter or ball mill.

Any one of the four latter mills will reduce the materials so that they will pass through a 30-inch mesh. The reduction previous to burning is usually completed in a tube mill where 90 to 95 per cent of mixture should pass through a 100-mesh sieve.

In soft materials, such as are found in Mississippi, the entire crushing before grinding could be accomplished economically by a combination of ball mills and tube mills, or by comminuter and tube mills. In the use of chalky limestone the entire process of reduction may be accomplished in tube mills.

The cost of drying depends on the amount of moisture in the raw materials, the type of dryer used, and the cost of fuel. It has been estimated that the most improved dryer will evaporate seven or eight pounds of water per pound of coal.

Wet Process.

The wet process of manufacturing Portland cement is best adapted to plants located in the northern States and in Canada, where the raw materials used are frequently fresh-water marls and clay. The marl usually occurs in swamps which are covered with water in wet seasons, and often frozen over in winter. Such plants, therefore, can run only a portion of the year.

The marls and clays are usually excavated from the pits by means of steam shovels. In some plants the marl is thoroughly mixed with water in the pit and pumped to the mill through pipes. The marl is screened before mixing with the clay to remove pebbles, sticks and roots. The clay in some plants is dried and pulverized before mixing in order to determine more easily the per cent of the mixture. The materials are mixed in the proportion of about 75 per cent of marl and 25 per cent of clay. The mixture is ground in wet mills of the disc type and finally reduced in wet tube mills.

The slurry from the tube mills contains from 30 to 40 per cent of solid matter, and 60 to 70 per cent of water. From the tube mills the slurry is pumped to large tanks and analyzed. If it contains the proper percentages of marl and clay, it is conveyed to the rotary kiln and burned.

The daily output of a 60-foot rotary kiln, using the wet process, is from 80 to 120 barrels, as compared with 160 to 180 barrels of a dry mixture. The difference is due to the great amount of water to be removed in the wet process. The cost per barrel in a wet mixture is 30 to 50 per cent greater than in the dry process.

PREPARING SLAG FOR CEMENT.

In iron-producing districts true Portland cement may also be made from a mixture of blast-furnace slag and pure limestone. The slag contains a sufficient amount of silica and alumina for the mixture. In addition it usually carries from 30 to 40 per cent of lime. By the addition of a pure limestone the proper percentages of a Portland cement are obtained.

In American cement plants the two materials are ground separately and then mixed in proper proportions. The mixture is then finely pulverized in tube mills and conveyed to rotary kilns and burned.

Where a good quality of slag and limestone can be obtained, the cost of making cement is reduced to a minimum. The process requires but little skilled labor and a relatively cheap plant.

Burning.

After the raw materials are carefully mixed and ground they are burned to a semi-vitrified mass called clinker, in kilns specially designed for the purpose.

The first kilns used in the manufacture of Portland cement were the stationary, intermittent, upright kilns, similar to those now generally in use in burning lime. They have some advantages over the more modern kilns. The original cost of construction is smaller, and less fuel is required. But in this country, where fuel is comparatively cheap, the object to be attained is as large an output as possible. For this reason, therefore, the rotary kiln has become very popular, and in all the modern, up-to-date plants they have displaced the upright kilns. The upright kilns are still in use in Europe.

The rotary kiln is a steel cylinder from 5 to 7 feet in diameter, and from 60 to 150 feet long. It is lined with the best fire brick to withstand the enormous heat necessary to burn the raw materials.

The kiln is inclined at about one-half inch to the foot. The mixture to be burned is fed into the upper end. The rotation of the kiln and the action of gravity gradually force the material through the kiln. In passing through it comes in contact with intense heat generated by the combustion of fuel gases, driving off the water and the carbon dioxide, and forming a chemical combination of lime, silica, alumina and iron oxide. The resulting mass falls out at the lower end of the kiln as clinker.

The fuel is fed into the kiln at the lower end just above the opening through which the clinker falls out. If coal is used as a fuel it is first finely crushed and thoroughly dried, and by means of an automatic feeder is forced into the kiln.

Fuels.

Coal.—The most common fuel used in the manufacture of Portland cement is bituminous coal. A coal high in volatile matter and low in ash has been found to be more desirable than coals containing a high per cent of carbon, such as anthracite and semi-bituminous coals.

A coal which contains more than 2 per cent of sulphur should not be used.

The following table gives the analyses of coals now used in different Portland cement plants in the United States:

TABLE 10.

ANALYSES OF KILN COALS.*

Volatile matter	32.90	38.10	31.38	35.41	35.26	39.52	39.37	31.87	37.44	38.00
Fixed carbon	54.66	53.24	58.23	56.15	56.33	51.69	55.82	51.05	53.72	51.72
Sulphur	n.d.	n.d.	n.d.	1.30	1.34	1.46	0.42	n.d.	n.d.	n.d.
Ash	10.25	8.06	9.42	6.36	7.06	6.13	3.81	5.22	5.50	5.38
Moisture	2.19	0.60	1.03	2.08	1.35	1.40	1.00	11.86	3.334	4.90

Before the coal is used in the kiln the large lumps and nut coal are first crushed and reduced to slack in an ordinary crusher. It is then taken to the dryer where all the hydroscopic or mechanically held water is driven off. This is most economically done in a rotary dryer, in much the same way as the raw clay and the limestone are dried. Care should be taken in drying the coal not to raise the temperature high enough to drive off any of the volatile combustible gases.

After the coal has been dried it is crushed and pulverized so that at least 85 per cent of it will pass through a 100-mesh sieve. The finer the coal is pulverized the more thorough is the combustion, and the better the results in the kiln. A poor coal, if finely pulverized, will give better results than a higher grade of coal coarsely ground. For this reason it is desirable to get the run of the mines, the original cost of which is cheaper, requires less crushing, and is as good as the hard lump coal.

The cost of coal as a fuel depends on the production-cost, the quality of the coal, the kind of kilns used, and the degree of fineness to which it is crushed before using.

From 200 to 300 pounds of coal are used in the power plant and in the kilns in the manufacture of a barrel (380 pounds) of Portland cement.

The cost of crushing, drying and finely pulverizing the coal, conveying it to the kilns, allowing for repairs, and interest on a four-kiln plant, will vary from 20 to 30 cents per ton, or about 3 to 5 cents

*Cements, Limes and Plasters, E. C. Eckel, 1905, p. 513.

per barrel of cement. In the average plant using coal as a fuel, about one-third of the total cost of the cement may be chargeable to fuel. The question of cheap fuel should, therefore, be an important factor in determining the location of a Portland cement plant.

Oil.—Oil was formerly used in Pennsylvania Portland cement plants as a fuel in rotary kilns; but its use has been abandoned for coal. Oil is used in some of the wesern plants where good heating coals cannot be obtained at reasonable prices.

It is claimed that from 11 to 14 gallons of oil, used in a rotary kiln, will burn one barrel of cement. On this basis, 1 gallon of oil is equivalent to about 20 pounds of coal.

Natural gas.—In sections of the country where there is natural gas it is found to be a very economical fuel. The gas is fed into the kiln by means of a large gas burner. It is found to be as good a fuel as coal and requires much less labor and storeroom to feed it to the kiln.

Producer gas.—At present there are three cement plants in the United States using producer gas as a fuel. Only one of these has been successful in obtaining an economical fuel consumption.

It has been shown by experiments carried on by the United States Geological Survey Coal-testing Plant at St. Louis, that the best quality of producer gas is obtained from bituminous coals and lignites. This gas can be ignited in internal combustion engines for the development of power, with a fuel economy of more than 50 per cent. A number of bituminous coals were converted into producer gas and burned in gas engines with a gain in power of 2.6 per cent more than when coal was burned under a common boiler in the production of steam power.

It was further shown that gas of a higher quality can be obtained from lignites and low grade coals than from the best Pennsylvania and West Virginia bituminous coals. The gas obtained from a ton of lignite, and burned in a gas engine, produced as much power as a ton of the best bituminous coal burned under a common boiler.

In his investigations of the lignites of Mississippi Dr. Calvin S. Brown, assistant geologist of the State Survey, has shown that there are a large number of workable veins of lignite in the State. It is quite possible, therefore, that a high quality of producer gas could

be made from the lignites of Mississippi, and a more economical power produced than can be obtained by using Alabama, Kentucky and Illinois coals.

TABLE 11.

ANALYSES OF MISSISSIPPI LIGNITES.

Moisture	13.61	12.51	13.50	8.72	14.61	14.90
Volatile matter	37.14	41.40	39.66	34.64	38.51	39.21
Fixed carbon	42.10	33.93	36.50	22.84	39.10	35.57
Ash	7.15	12.16	10.34	33.80	7.78	10.32
Total	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	2.64	2.77	4.10	2.76	1.28	0.56
Moisture	15.22	13.04	14.60	13.20	12.26	11.61
Volatile matter	42.38	36.68	30.59	40.16	37.43	34.61
Fixed carbon	34.91	35.62	35.21	31.24	41.91	42.47
Ash	7.49	14.66	11.60	15.40	6.37	11.31
Total	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	0.91	0.48	1.83	1.20	0.94	2.66

GRINDING THE CLINKER.

As the burned clinker emerges from the rotary kiln it has a temperature ranging from 300° F. to 2,500° F., or about 13 per cent of the total amount of heat utilized in the kiln. Before it can be crushed the clinker must in some way be cooled.

A number of devices have been invented to cool the clinker in the most rapid and at the same time in the most economical way. In some plants the hot clinker, on its journey from the kiln to the storage room, is subjected to a spray of water, the evaporation of which absorbs the heat of the clinker. In this method of clinker-cooling none of the heat of the clinker is utilized. Since the amount of heat carried off in the clinker is so great, efforts have been made to utilize the heat of the cooling clinker. This has been the most successfully done by the two-stage rotary cooler.

The principle on which the cooling is done is here summarized from a description of the cooling system at the main Atlas cement plant, by Stanger and Blount in Proc. Inst. Civil Engineers, Vol. 145, pp. 57–68, 1901.

The hot clinker from the kiln falls into a rapidly revolving cylinder about 30 feet long and 3 feet in diameter, otherwise similar in construction to the rotary kiln. At the end of the cylinder opposite the kiln is admitted a blast of cool air which passes through the cylinder,

cools the clinker, and is admitted into the kiln in a highly heated condition. At the end of the first cylinder the clinker passes through a crusher which is kept cool by a spray of water. The clinker passes from the crusher through a second cylinder, 60 feet long and 5 feet in diameter. From the second cylinder the clinker is conveyed to the crushers.

In burning the raw materials at a high temperature the clinker thus formed is a very hard semi-vitrified mass which must be pulverized to a fine flour before it can be called cement. The best Portland cements are now ground so that from 90 to 95 per cent will pass a 100-mesh sieve. The process requires a great amount of power and heavy machinery.

It is estimated by Mr. E. C. Eckel that, in a Portland cement plant using the dry process of manufacture, it requires about the same amount of power and similar machinery to crush the clinker as that used in crushing the raw materials. "It must be remembered that for every barrel of cement produced, about 600 pounds of raw material must be pulverized, while only a scant 400 pounds of clinker will be treated; that the large crushers required for some raw materials can be dispensed with in crushing clinker, and that the raw side rarely runs full time."*

RETARDER FOR QUICK-SETTING CEMENTS.

A small amount of calcium sulphate, usually in the form of crude gypsum or plaster of Paris, is necessary in the manufacture of Portland cement to retard the quick-setting, high-limed clinker produced in the rotary kilns. The amount used in most American plants varies from 2 to 3 per cent. Used in large quantities it may even accelerate the set and greatly weaken the cement. The calcium sulphate should be intimately mixed with the cement, and that this may be thoroughly done it is usually put in and ground with the clinker.

PORTLAND CEMENT MATERIALS OF MISSISSIPPI.

GENERAL GEOLOGY.

Cement materials of Mississippi consist of hard limestones, chalk, clays and shales. Inasmuch as the chalk of this State is a comparatively hard rock it will be treated as a limestone.

Limestone, the principal ingredient necessary in the manufacture of Portland cement, is found in four geologic periods of the State,

*Limes, Cements and Plasters, 1906, p. 531.

widely differing from each other in age and location. In each period shales or clays overlie the limestones. The four periods will be described in the order here given.

(1) Devonian.
(2) Carboniferous.
(3) Cretaceous.
Selma chalk.
(4) Tertiary.
Vicksburg limestone.

Devonian.

Along the Tennessee River, and for a distance up all the streams flowing into the Tennessee from the State of Mississippi, are beds of limestone representative of the Lower Devonian. The line of separation of the Devonian and Carboniferous rocks has not been mapped in Mississippi. The Devonian rocks are represented by a dark gray limestone and interbedded shales, with an occasional stratum of fine-grained standstone. The limestone contains a high per cent of insoluble matter which occurs in chemical combination and not in the form of free silica or sand.

The following section of the Devonian on Yellow Creek, Tishomingo County, was obtained by the writer:*

Section of Devonian on Yellow Creek.
Sec. 22, T. 1 N., R. 10 E.

	Feet
Thin-bedded, impure limestone at base, changing gradually to a bluish limestone at top of cliff	95
Compact blue limestone, non-fossiliferous	40
Dark gray limestone containing numerous Devonian fossils	10
Dark pure limestone to water's edge	5

On the north bank of Yellow Creek, near its mouth, the limestone is overlain by thin strata of aluminous sandstone and shale.

A reproduction of the outcrop near the mouth of Yellow Creek is found on Whetstone Creek near Short postoffice.

Section on A. L. Bugg's Land, near Mouth of Whetstone Creek.†

	Feet
Angular chert, flint and hornstone	100
Dark blue shale containing iron pyrite; very fossiliferous in lower part	30
Thin-bedded, fine-grained, shaly limestone, with thin bands of fine-grained sandstone or whetstone varying from a fraction of an inch to 12 inches in thickness	20

*Geology and Mineral Resources of Miss., U. S. Geol. Surv. Bull. No. 283, p. 9.
†Ibid p. 10.

It is quite probable that the dark blue limestone which is found at the mouth of Bear Creek is the uppermost member of the Devonian.

The Devonian of this State includes shale and limestone suitable for hydraulic and Portland cements.

TABLE 12.

ANALYSES OF DEVONIAN LIMESTONE FROM TISHOMINGO COUNTY.

	1	2	3	4
Insoluble matter (SiO_2)	54.201	35.281	42.00	48.18
Alumina (Al_2O_3)	1.064	1.914	1.98	3.43
Iron oxide (Fe_2O_3)	0.903	1.581	6.02	3.13
Lime (CaO)	23.247	32.603	23.25	39.47
Magnesia (MgO)	0.788	0.630	0.27	3.19
Carbonic acid	15.572	27.643	*24.10	5.06
Organic matter and water	3.752		0.40	0.40
Potash	0.473	0.348	......	......
Sulphur trioxide	......	......	1.50	2.23

1, 2. Dr. E. W. Hilgard, analyst.
3, 4. Dr. W. F. Hand, analyst.

Carboniferous.

The Carboniferous rocks in Mississippi include beds of limestone, shale, chert and sandstone extending in age from the Ordovician to and including the Mississippian. Oolitic limestone suitable for the manufacture of Portland cement is found near the top of the Carboniferous rocks in Mississippi, and is the equivalent of the St. Genevieve limestone of western Kentucky, and the famous building stone of Bedford, Indiana. In Alabama this rock is quarried for burning lime and building stone.

The oolitic limestone is dark gray to white, and is made up almost exclusively of small, rounded concretions called oolites. It is practically free from impurities. A thickness of 30 feet or more is exposed in the bluffs on Bear Creek as far south as Mingo.

The distribution of the oolitic limestone and accompanying shales is confined to that part of Tishomingo County lying north of Mingo, along Bear Creek and its tributaries, and in one locality on Macky's Creek. In the hills to the west the Paleozoic rocks are covered by later deposits of Cretaceous and Lafayette.

On the west side of Cypress Pond, about 1 mile north of west of the steel bridge across Bear Creek near Mingo, on land now belonging to Mr. William Southward, the limestone forms a bluff 30 to 35 feet high. Its thickness below the surface has not been determined. The

*Volatile matter.

limestone is overlain by a bed of dark blue shale which weathers to a tough blue clay. The top of the limestone along the pond has about the same elevation as the base of the shale bed in the section at the steel bridge given below, so that the two may be taken together as one continuous section, the one at the bridge being a continuation upward of the Cypress Pond section.

Limestone outcrops in many of the branches flowing into Cypress Pond, and is frequently struck in wells on the west side of Bear Creek. Still farther north, on the Allsboro and Iuka road, the oolitic limestone outcrops in sections 22, 26 and 27, T. 4 N., R. 11 E. The oolitic limestone near Mingo is overlain by a bed of shale 23 feet thick, separated by a thin stratum of impure limestone 8 inches thick.

The following is a section of the bluff at the steel bridge near Mingo:

Section of the Bluff at the Steel Bridge near Mingo.

Residuary soil and Lafayette at the surface.........	x feet
Heavy-bedded limestone about.....................	20 feet
Compact, blue shale............................	15 feet
Thin ledge of impure limestone, upper 3 inches studded with fossils.................................	8 inches
Thinly laminated blue shale with an occasional fragment of impure dark limestone, water's edge.....	8 feet

The lowest shale bed is thinly laminated and contains more or less fine sand between the laminæ. The upper bed is more thickly laminated and freer from impurities.

The composition of the above limestones and shales is given below:

TABLE 13.

ANALYSES OF CARBONIFEROUS LIMESTONES AND SHALE, TISHOMINGO COUNTY.

	1	2	3
Silica (SiO_2)................................	1.57	10.91	54.46
Alumina (Al_2O_3)................................	1.94	8.17	14.92
Iron oxide (Fe_2O_3)................................	1.69	5.00	12.50
Lime (CaO)................................	52.75	47.06	2.56
Magnesia (MgO)................................	.36	0.16	0.00
Volatile matter (CO_2)................................	40.80	27.00	13.30
Sulphur (SO_3)................................	.32	0.85	.85
Moisture................................	.15	1.10	2.30
	99.48	100.25	100.89

1. Limestone from Cypress Pond near William Southward's house.
2. Limestone from Mingo bridge, Bear Creek.
3. Shale from Mingo bridge, Bear Creek.

CRETACEOUS.

TUSCALOOSA CLAYS.

The Tuscaloosa clays are well displayed in northeastern Mississippi. They have been more carefully studied in Tishomingo County, where they occur in thick deposits over large areas. These clays overlap the Carboniferous and Devonian limestones and in some cases outcrops of limestone and clay occur in the same section.

The following analyses are characteristic of the clays of Tishomingo and Itawamba counties:

TABLE 14.

ANALYSES OF TUSCALOOSA CLAYS OF MISSISSIPPI.*

	Silica (SiO_2)	*Alumina* (Al_2O_3)	*Ferric oxide* (Fe_2O_3)	*Lime* (CaO)	*Magnesia* (MgO)	*Sulphur trioxide* (SO_3)	*Moisture*	*Loss on ignition*
Pink clay, 6 miles north of Iuka, Tishomingo County	†38.11	36.42	11.73	.60	.14	Tr.	.87	11.96
White clay, 6 miles southeast of Iuka, Tishomingo County	†66.85	20.54	3.77	.21	.18	Tr.	.59	8.00
White potter's clay, 5 miles south of Iuka, Tishomingo County	†68.65	18.99	2.77	.20	.20	Tr.	1.09	7.34
White clay, 5 miles south of Iuka, Tishomingo County	‡80.07	11.46	.57	.12	.37	n.d.	X6.81	.60
Tuscaloosa clay, 15 miles south of Iuka, Tishomingo County	†80.03	12.00	1.68	.24	.26	Tr.	.48	4.82
Tuscaloosa clay, 12 miles south of Iuka, Tishomingo County	§90.877	2.214	.126	.140	Tr.	n.d.	X6.93	......
White potter's clay, 14 miles southeast of Fulton, Itawamba County	†59.12	27.44	4.39	.34	.28	Tr.	.54	7.40
White potter's clay, 14 miles southeast of Fulton, Itawamba County	†62.58	27.58	1.57	.40	Tr.	Tr.	.77	6.77
Tuscaloosa clay, 14 miles southeast of Fulton, Itawamba County	†71.53	14.46	4.14	.62	.55	n.d.	2.17	5.91

SELMA CHALK.

The Selma chalk of Mississippi includes a great thickness of chalky limestone commonly known as "rotten limestone" of Cretaceous age. In Bulletin No. 283, U. S. Geological Survey, the writer describes the Selma chalk as "a mass of loosely semi-cemented lime carbonate, the

*Bull. 283 U. S. Geological Survey, Crider, pp. 51–55.
†W. F. Hand, State chemist, analyst.
‡J. Blodgett Britton of Philadelphia, Pa., analyst.
§Dr. E. W. Hilgard, analyst.
XWater and organic matter.

upper division of which is of exceptional purity. Where it is typically exposed along the larger streams it bleaches to a white appearance and is called the 'white chalk' bluffs. To the casual observer the entire formation has much the same appearance, but it may be separated into three natural divisions, based primarily on chemical analysis, (*a*) the transition beds at the base, (*b*) the 'blue rock,' or more clayey unweathered portion, and (*c*) the rotten limestone, or chalk, including the upper portion of the formation.

"(*a*) The lowest division contains a large amount of free sand which was washed into the Selma sea from the Eutaw and the older land surface to the east. This forms the transition beds from the extremely sandy strata of the Eutaw to the deep-sea deposits of lime carbonate which characterizes the Selma chalk. The amount of sand is greatest at the base and becomes less and less upward until it finally disappears entirely." This lower portion would not be suitable for cement on account of the great amount of free sand it contains. Fortunately, however, the sandy portion is confined to the lower division of the formation and can be easily avoided in using the overlying limestone for cement.

"(*b*) The middle division contains a relatively large amount of clay and when freshly dug is of a bluish color. It is found in the deep wells and recognized by the drillers as 'blue rock.' The great amount of clay in the lime carbonate renders the rock impervious to water. The fine supply of artesian water stored in the underlying Eutaw sands is held in place and prevented from escaping upward by means of the 'blue rock' of the Selma.

(*c*) "The uppermost division contains a greater amount of lime carbonate and much less clay than the 'blue rock' and likewise a smaller amount of free silica than the lowest division. Some of the analyses of this chalk show 98 per cent of calcium carbonate.

"In places a hard crystalline limestone, somewhat silicified, forms a capping to some of the hills of the Selma. Hard flint rock and a thin strata of sandstone are reported in a deep well-boring at Livingston, Ala."

The Selma in Mississippi corresponds to the formation of the same name in Alabama. The white chalk bluffs along Tombigbee, Warrior and Alabama rivers may be seen in numerous places in Dallas, Hale,

Sumter and Green counties, Alabama. It is all of the same geologic age, and once known it may be easily recognized.

THICKNESS.

The Selma attains its greatest thickness in central Alabama, where it is reported to be 1,200 feet. It decreases in thickness to the east, disappearing entirely in the eastern part of the State. East of Montgomery the three divisions are mapped as one formation. In western Alabama it has a thickness of 925 to 950 feet, while in Oktibbeha County, Mississippi, it has a thickness of about 800 feet. From this point northward the formation continues to thin and finally disappears entirely near Camden, Tennessee. The area of the State underlain by the Selma is shown by the light green on the map. The region is known as the "prairies" and may be easily recognized by the dark rich loams at the surface. The disintegration of the Selma forms one of the richest soils in the State. In Alabama the Selma area forms one of the richest cotton belts in the South and is known as the "Black belt."

In comparatively recent geologic times the entire area of the Selma was covered by the Lafayette, a thin deposit of sandy loam. The greater part of the Lafayette has been carried away by the streams. In the inter-stream areas however, and on the more level lands near the streams, there are still small patches of Lafayette which have suffered but little erosion since its deposition. In consequence of this fact there are two distinct and widely different soils which are found in this region. These are the "post oak" and the "prairie" soils. The Lafayette in this area has a maximum thickness of about 13 feet.

The "post oak" soils are usually found on the higher inter-stream areas where there has been least erosion. The soil is poor and produces a scrubby growth of post oak and black jack. In the early settlement of the region the "post oak" land was first cleared, but at present it is mostly used for grazing.

The "prairie soils" are found on the rolling lands from which the Lafayette has been entirely removed so that the rich black loam, formed by the disintegration of the underlying Selma limestone, is at the sufrace. The "prairie soils," therefore, are residual soils *in situ*, and form the most fertile lands of eastern Mississippi.

In places all the Lafayette and even the residual soil of the Selma have been removed by erosion, leaving the white chalky limestone of the Selma at the surface. On looking for the outcropping Selma it may be more readily found along the streams, on the steep hillsides and in the railroad cuts.

Inasmuch as this is to be the final report on the cement materials of the State for some time, space will be taken to describe a large number of outcrops of the Selma limestone, much of which is very similar in appearance. A fair series of analyses has been made of the limestone from different localities, giving some idea of the value of the Selma for cement. It must be understood, however, that at no locality has the Selma been found to contain all the constituents necessary in the manufacture of either hydraulic or Portland cement. It becomes valuable as a cement product when used in connection with clay. All the limestone found in the Selma area is not of value for cement because of the lack of good clay near it. Only those outcrops, therefore, which are near good clay outcrops can profitably be utilized for cement. The clay in the geologic section immediately overlying the Selma, known as the Porter's Creek, is suitable for mixing with the limestone. The possibility of using this clay will be taken up under the head of Porter's Creek clay.

DISTRIBUTION.

That part of the State embraced within the area represented on the map by the light green color is underlain by the Selma chalk. The limestone does not show at the surface over the entire area shown on the map owing to the covering of sandy loam and residual soil which, over the greater part of the area, completely covers the limestone. This covering is comparatively thin, as is shown in wells, railway cuts, along the streams and on many hillsides where the atmospheric waters have carried away the soil covering, leaving the Selma limestone exposed at the surface.

Corinth and Vicinity.—The town of Corinth is built in the valley of a small stream which flows into Tuscumbia River. On the west side of the town is a low range of hills which rise 30 to 40 feet above the valley. About $\frac{1}{8}$ of a mile west of the station on the Southern Railway, is a cut through a small ridge showing from 5 to 8 feet of surface sandy loam, with an equal thickness of Selma limestone,

which extends to the bottom of the cut. The Selma at this place can hardly be called a limestone. It is the "blue rock" which occurs near the bottom of the formation, and is more properly a compact calcareous clay which can be broken into rectangular blocks. There are small needle-like crystals of selenite in the cracks and on exposed surfaces. The thickness of the Selma at Corinth is less than 100 feet.

TABLE 15.

ANALYSIS OF SELMA LIMESTONE FROM CORINTH.

Silica (SiO_2)	25.40
Alumina (Al_2O_3)	6.88
Iron oxide (Fe_2O_3)	8.62
Lime (CaO)	26.37
Magnesia (MgO)	.58
Volatile matter (CO_2)	23.70
Sulphur trioxide (SO_3)	0.64
	92.19

The above analysis shows a high per cent of silica, which is characteristic of the lower beds of the Selma. Higher in the formation the percentage of lime steadily increases, while the siliceous material decreases correspondingly. Purer limestone is found in the railway cuts west of Corinth.

The Selma may be found underlying the surface covering for 6 to 10 miles west of Corinth, and for 3 miles east. It gradually thins to the east and finally disappears completely in the low north and south range of hills 3 miles east of town.

At the western end of the 90 foot cut on the new line of the Illinois Central Railway, 3 miles east of Corinth, the blue limestone of the Selma extends to the bottom of the cut. At the eastern end it forms a thin stratum and finally disappears completely. The lowest member of the Selma is underlain by a bed of oxidized, calcareous, sand-bearing fossils.

The Selma is exposed in almost every cut of any size along the Southern Railway from Corinth to the Tennessee State line. A few hundred yards west of Wenasoga, 12 feet or more of bluish calcareous clay are exposed in the railway cut. At this point the Selma is much thicker than it is at Corinth. At the little town of Chewalla, across the line in Tennessee, it was penetrated in a well at a depth of 350 feet. There is quite a thickness of overlying transported soil, so that the limestone is at least 300 feet thick.

The Selma is encountered in digging wells at Danville, Rienzi and Thrasher, but these towns are near the eastern edge of the Selma, which, as is shown by the well records, contains more or less sand. These towns are located on the Mobile and Ohio Railway, which follows along the second bottoms of the Tuscumbia River, and consequently there are no outcrops of the Selma at the surface.

Booneville and Vicinity.—In the deep cut on the Mobile and Ohio Railway, in the town of Booneville, the typical Selma limestone is exposed. There is a thick covering of sandy loam (Lafayette) overlying the limestone in the vicinity of Booneville. Many of the wells obtain their supply of water from the base of the Lafayette. The compact nature of the Selma prevents the water from penetrating it. There are many small springs found at the contact between the Lafayette and the underlying Selma.

The following record of the Booneville Waterworks Company's well, furnished by Mr. A. W. Hurley, driller, will give some idea of the thickness of the Selma at this place:

Section of Booneville Waterwork's Well.

	Feet
13. Surface red clay	18
12. Selma "blue rock"	52
11. Bluish green sandy clay with shells	3
10. Blue sand containing water	40
9. Hard rock	1
8. Blue sand containing water	7
7. Blue hard rock	1½
6. Clay ("soapstone") / 5. Sand / 4. Clay ("soapstone") / 3. Sand	188
2. Hard rock at 307 feet	1½
1. Gray sand containing green sand grains	35
Total depth of well	347

From the above record it will be seen that the limestone at Booneville is 52 feet thick. One-fourth of a mile east of this town it is only 25 feet thick, and ¾ of a mile east it cuts out entirely. It outcrops in the hills west of the town and is encountered in all the deep wells as far west as Jumpertown. The Mobile and Ohio Railway follows, approximately, the eastern limit of the Selma between Booneville and Tupelo. The eastward extension of the Selma at Booneville is due to the fact that the divide between the waters of Tuscumbia and

Tombigbee rivers have suffered but little erosion. South of the divide the headwaters of Tombigbee River have carried away a large amount of the Selma and caused the contact between the Selma and the underlying Eutaw green sands to swing westward in the vicinity of Wheeler, Baldwin and Guntown.

At Guntown the lowest beds of the Selma are exposed in the railway cut just north of the station. There is a compact ledge of fossiliferous limestone about 2 feet thick underlain by a bed of green sand which extends to the bottom of the cut. This doubtless corresponds to strata No. 11 in the Booneville section. There is a strong southward dip of the Selma as shown in the railroad cut at Guntown. The main body of the Selma lies west of Guntown. The basal members here, as at all other places where they are exposed, contain too much sand to be used in the manufacture of Portland cement.

Tupelo and Vicinity.—The town of Tupelo is built in the valley of Old Town Creek, a large tributary to Tombigbee River. In the lower portions of the town the alluvial soil is 20 feet thick. The hills to the east have a thin covering of Lafayette. To the northwest the Lafayette and residual Selma form the fertile farming lands. The only evidence of the presence of the Selma here is found in the wells which extend below the surface soils. Below is a record of an average artesian well in Tupelo:

Well Record at Tupelo.
R. B. McVay, Driller.

	Feet
Surface soil	20
"Blue rock" with some sand (Selma)	100
Blue limestone (Selma)	130
Fine gray sand, water-bearing	10
Clay ("soapstone")	4
White sand, water-bearing	10
Clay ("soapstone")	20
Fine white sand, thickness undetermined.	

The above record shows 230 feet of Selma limestone. The upper 100 feet of "blue rock" is reported as containing some sand. This is perhaps a calcareous green sand or else it is a horizon in the Selma not yet discovered at the surface. The latter theory is hardly probable, however, since so great a thickness would not have escaped detection in the detailed work done on the formation in Alabama and along the Tombigbee River in Mississippi.

The first cut on the Mobile and Ohio Railway south of Tupelo exposes the Selma from the surface to the bottom of the cut. All the deep cuts from here to Verona penetrate the surface soils and reach the Selma. It also outcrops on the sides of the wagon road and in the open field about 2½ miles south of Tupelo. In other places along the road between Tupelo and Verona, and in numerous places west of Verona, the Lafayette has been removed by erosion, exposing the Selma. On the more level lands the residual soil of the Selma forms the well known "prairie soil." During the rainy season the constant kneading of the "prairie soil" by wheels of vehicles and horses' feet forms a tough plastic clay which, when once recognized, may never be mistaken. Even if there is no outcrop of the Selma near, the "prairie soil" indicates that the Selma is but a few feet, or perhaps a few inches, below the surface.

A sample of the Selma collected from the roadside about 2½ miles south of Tupelo shows the following analysis.

TABLE 16.

ANALYSIS OF SELMA LIMESTONE 2½ MILES SOUTH OF TUPELO.

Silica (SiO_2)	22.76
Alumina (Al_2O_3)	4.56
Iron oxide (Fe_2O_3)	6.46
Lime (CaO)	34.31
Magnesia (MgO)	.05
Volatile matter (CO_2)	28.25
Sulphur trioxide (SO_3)	.43
Moisture	2.10

Fine exposures of the Selma are found on Coonewah Creek about 5 miles west of Tupelo. It is overlain in places by 6 to 10 feet of yellow clay. The Selma continues westward to within 3 or 4 miles of Pontotoc. In southeastern Pontotoc County it is reported to be 750 feet thick.

A sample of Selma collected by W. N. Logan from a point 1 mile west of Tupelo, on the Tupelo and Pontotoc road, shows the following analysis:

TABLE 17.

ANALYSIS OF SELMA LIMESTONE 1 MILE WEST OF TUPELO.

Silica (SiO_2)	14.84
Alumina (Al_2O_3)	15.59
Iron oxide (Fe_2O_3)	4.50
Lime (CaO)	32.89
Magnesia (MgO)	.41
Volatile matter (CO_2)	27.10
Sulphur trioxide (SO_3)	3.30
Moisture	1.08
	99.71

The thickness of the Selma as shown in the wells at Verona is about the same as it is in Tupelo. The following is a record of one of the wells in Verona:

Well Record at Verona.
R. B. McVay, Driller.

	Feet
Surface soil	21
Light colored Selma	80
Blue limestone, Selma	160
Gray sand, water-bearing	10
Compact, sticky sand	30
Gray sand, water-bearing	15
Black clay, "soapstone"	20
Fine gray sand, water-bearing	x

The entire thickness of the Selma here is 240 feet. No sand is reported from the upper 80 feet as in the well at Tupelo. The well is located in the lowest part of the town near the station. The Selma comes to the surface in places just west of town.

Okolona and Vicinity.—One of the best exposures of the Selma limestone in the northern and central portions of the Selma area is found in the town and vicinity of Okolona. In a few places the Lafayette sandy loam is present, but from the greater portion of the area it has been removed, leaving large patches of exposed limestone known as "bald prairies." The limestone has become white by reason of long exposure to sun and rain. In this respect it resembles the "white chalk" exposed in the bluffs along Noxubee and Tombigbee rivers.

The numerous outcrops of the Selma in southeastern Chickasaw and western Clay counties have been carefully described by Dr. Hilgard.*

The country is dotted with outcrops of the Selma along Chookatonkchie, Houlka, Oka Tibbeha or Tibby creeks, and on the eastern slope of Pontotoc Ridge, projections of which extend southward between the above mentioned streams. The limestone in northwestern Clay County has been penetrated in wells at a depth of about 500 feet.

A sample of the limestone from the railroad cut at the Mobile and Ohio station, Okolona, was burned in a forge for a period of 15 min-

*Agriculture and Geology of Mississippi, pp. 79–81.

utes. The rock was heated to a white heat and slaked by pouring water on it. It immediately broke down into a beautiful white lime. The following analyses were made of this limestone:

TABLE 18.

ANALYSES OF SELMA LIMESTONE FROM OKOLONA.

	1	2
Silica (SiO_2)	8.80	8.70
Aluimna (Al_2O_3)	2.86	0.00
Iron oxide (Fe_2O_3)	4.08	6.00
Lime carbonate (CaO)	45.51	45.62
Magnesium carbonate (MgO)	.36	1.72
Volatile matter (CO_2)	31.11	34.40
Sulphur trioxide (SO_3)	.38	1.11
Moisture	6.35	1.10

The following analysis of the same limestone was made by Dr. E. W. Hilgard.*

Insoluble matter (mostly silica) (SiO_2)	10.903
Alumina (Al_2O_3)	1.957
Peroxide of iron (Fe_2O_3)	1.421
Lime (CaO)	†45.791
Magnesia (MgO)	‡0.877
Carbon dioxide (CO_2)	35.725
Alkalies (K_2O, Na_2O)	0.568
Organic matter and water	2.840

The eastern edge of the Selma south of Tupelo follows, approximately, the boundary between Itawamba and Lee counties southward to the Monroe County line. From here to Columbus it is almost a due north and south line, rarely extending more than 3 miles west of Tombigbee River. Outcrops are frequent from the eastern to the western borders of the formation.

Starkville and Vicinity.—In the eastern half of Oktibbeha County the Selma limestone is characteristically developed. A few small patches of the Lafayette still remain on some of the divides. The rest of the surface is formed by the residual loam of the "prairie soil," and the white rock of the Selma.

One to ten feet of Selma limestone may be seen in almost every cut along the Illinois Central Railway from Starkville to West Point.

Similar outcrops occur along the Mobile and Ohio Railway from Starkville to Artesia.

*Geology and Agriculture of Mississippi, 1860, p. 101.

†Equals lime carbonate ($CaCO_3$) 81.77.

‡Equals magnesium carbonate ($MgCO_3$) 1.84.

The thickness of the Selma in the city well at Starkville is about 750 feet, with 50 feet or more exposed in the hills to the north.

The character of the limestone collected from various localities in Oktibbeha County is shown by the following analyses:

TABLE 19.

ANALYSES OF SELMA LIMESTONE FROM OKTIBBEHA COUNTY.

	1	2	3	4	*Average*
Silica (SiO_2)	2.89	2.33	3.03	2.55	2.70
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	1.53	1.72	1.92	1.96	1.78
Lime carbonate ($CaCO_3$)	94.10	94.35	93.60	94.07	94.03
Magnesium carbonate ($MgCO_3$)	1.84	1.82	1.64	2.12	1.85
Water (H_2O)	.36	.44	.42	.52	.44

By a proper admixture of clay with any of the above samples of limestone the product would make an excellent Portland cement. The per cent of lime carbonate is high with a corresponding low per cent of iron oxide, alumina and magnesium carbonate.

The following samples of Selma limestone, collected by W. N. Logan from Oktibbeha County, were analyzed with the following results:

TABLE 20.

ANALYSES OF SELMA LIMESTONE FROM OKTIBBEHA COUNTY.

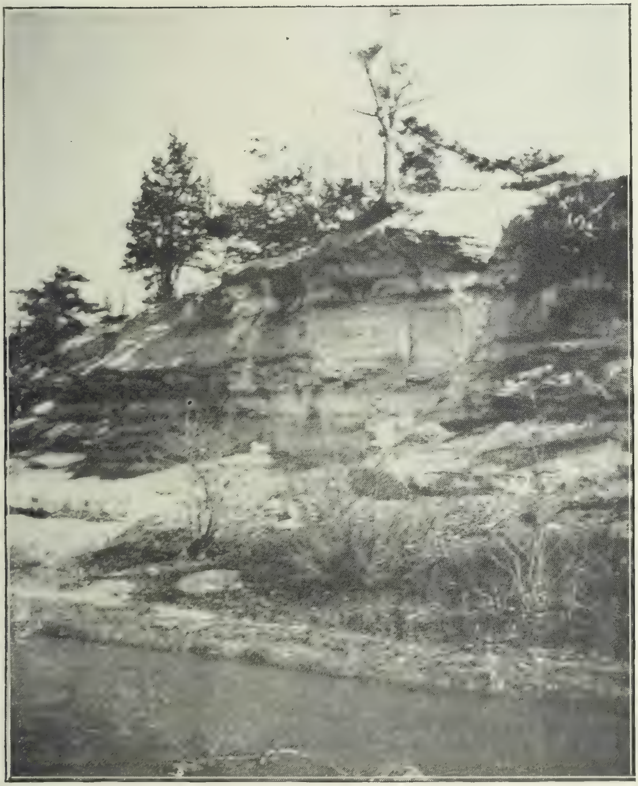
	1	2	3	4	5	6
Silica (SiO_2)	29.98	25.27	9.84	20.60	17.03	18.82
Alumina (Al_2O_3)	5.45	4.81	.19	7.63	21.00	.23
Iron oxide (Fe_2O_3)	5.60	10.35	2.58	4.62	3.33	2.80
Lime (CaO)	31.62	32.85	38.65	21.81	29.29	40.02
Volatile matter (CO_2)	24.50	25.60	42.05	23.15	28.20	34.02
Magnesium oxide (MgO)	.14	.84	.18	.81	0.00	.96
Sulphur trioxide (SO_3)	.21	.62	2.05	.25	.72	2.53
Moisture	1.50	.40	.94	.85	.75	1.15

1. Agricultural College.
2. Near Osborn.
3. Reynolds farm, 1 mile west of Starkville.
4. Howard Brick Yard, Starkville.
5. Howard Brick Yard, Starkville.
6. Mayhew road, 1 mile east of Agricultural College.

The occurrence of Selma limestone in southern Monroe, Lowndes, Noxubee and Kemper counties has been described in detail by the writer in Bulletin 260, U. S. Geological Survey, 1904, pp. 510–521. A large number of samples from these counties were collected and analyzed in the U. S. Geological Survey laboratory.

Macon and Vicinity.—The limestone at and near Macon deserves special mention on account of the large amount of material in sight,

PLATE I.



SELMA CHALK BLUFF, MACON.

the ease with which it could be quarried, the nearness to deposits of clay and the facilities offered for transportation.

The bluff on Noxubee River at the mouth of Macon Creek, near the town of Macon, is about 40 feet high, and extends more or less unbroken to the mouth of the Noxubee River. The entire bluff, except 5 or 10 feet of surface soil, is formed of the Selma limestone. Other outcrops occur along all the principal streams flowing into the Noxubee River, and in the railway cuts as far south as Scooba.

The limestone, viewed from a distance, appears to be a homogeneous mass of white chalk. On close examination, however, it is found to have an amygdaloidal structure, as if small fragments of limestone had been cemented into a compact mass. There are few joints or stratification lines visible. Occasional concretions of iron pyrite ranging from the size of a buckshot to a hen's egg occur imbedded in the limestone. After long exposure to the weathering agents the sulfide of iron changes to the oxide, leaving rusty iron stains on the rocks.

The following analyses were made of the limestone from the bluff at Macon:

TABLE 21.

ANALYSES OF SELMA LIMESTONE FROM MACON.

	1	2
Silica (SiO_2)	9.09	13.03
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	7.47	7.43
Lime carbonate ($CaCO_3$)	80.99	76.71
Magnesium carbonate ($MgCO_3$)	.00	.36
Water	1.08	.95
Sulphur trioxide (SO_3)	0.00	.64

1. W. S. McNeil, U. S. Geol. Survey, Analyst.
2. W. F. Hand, State Chemist, Agricultural College, Analyst.

A sample of limestone was collected from the ridgeland 3 miles north of Macon and analyzed in the laboratory of the U. S. Geological Survey with the following results:

TABLE 22.

ANALYSIS OF SELMA LIMESTONE FROM 3 MILES NORTH OF MACON.

(W. S. McNeil, Analyst.)

Silica (SiO_2)	8.52
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	6.60
Lime carbonate ($CaCO_3$)	83.88
Magnesium carbonate ($MgCO_3$)	.00
Water	1.00

Still another sample of the Selma was collected from Prairie Rock, 12 miles east of Macon. This rock is much harder than the ordinary Selma and breaks with a metallic ring. It has been used to some extent for building roads near Prairie Rock, but it soon breaks down into soil under the action of the weathering agents. A sample of this limestone was analyzed in the laboratory of the U. S. Geological Survey with the following results:

TABLE 23.

ANALYSIS OF SELMA LIMESTONE FROM PRAIRIE ROCK.

(W. S. McNeil, Analyst.)

Silica (SiO_2)	1.13
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	.68
Lime carbonate ($CaCO_3$)	98.36
Magnesium carbonate ($MgCO_3$)	Tr.
Water	.40

In southwestern Lowndes County excellent Portland cement materials are found along the divide between Tombigbee and Noxubee rivers.

On Mr. J. B. Brook's land near Crawford, much of the overburden has been removed, leaving the white Selma chalk at the surface. The limestone from this place contains about the proper proportions of lime carbonate, alumina and iron oxide for Portland cement. There is a small amount of magnesia, but not enough to injure it. To make a suitable cement this limestone must be mixed with a clay containing a low per cent of silica.

TABLE 24.

ANALYSIS OF SELMA LIMESTONE FROM CRAWFORD.

(Analysis furnished by J. B. Brooks.)

Silica (SiO_2)	8.88
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	5.94
Calcium carbonate ($CaCO_3$)	79.73
Magnesia ($MgCO_3$)	1.22
Loss	1.88

A residual clay of the Selma limestone from the same locality was analyzed with the following results. This clay, while it is a fairly good one, contains a rather high per cent of iron oxide and alumina to use with the limestone.

Plate II.

RESIDUAL CLAY AND LAFAYETTE OVERLYING SELMA CHALK, MACON.

TABLE 25.

ANALYSIS OF CLAY FROM CRAWFORD.

Silica (SiO_2)	69.10
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	17.10
Calcium carbonate ($CaCO_3$)	1.60
Magnesium carbonate ($MgCO_3$)	.72
Loss	9.18

The Selma limestone may be seen along many of the streams, and in the railway cuts between Macon and Scooba. As a general thing there is only a thin covering of overburden on the ridges and slopes.

Five miles east of Shuqualak, Noxubee River has cut into the Selma limestone and formed a bluff on the east bank 50 feet high. A sample of this limestone collected by the writer* and analyzed in the laboratory of the U. S. Geological Survey, gave the following results:

TABLE 26.

ANALYSIS OF SELMA LIMESTONE 5 MILES EAST OF SHUQUALAK.

(W. S. McNeil, Analyst.)

Silica (SiO_2)	8.06
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	5.94
Lime carbonate ($CaCO_3$)	84.61
Magnesium carbonate ($MgCO_3$)	.06
Water	1.32

The high percentage of silica in the Selma at Wahalak, Bodea Creek and Scooba, indicates a change from the deep sea in which the Selma was deposited, to the more shallow waters which received the more siliceous deposits of the Ripley and the Porter's Creek formations.

The following analyses† of Selma limestone were made in the laboratory of the U. S. Geological Survey:

TABLE 27.

ANALYSES OF SELMA LIMESTONE FROM KEMPER COUNTY.

(W. S. McNeil, Analyst.)	1	2	3
Silica (SiO_2)	16.48	10.60	20.00
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	6.97	5.90	8.92
Lime carbonate ($CaCO_3$)	74.34	82.47	68.91
Magnesium carbonate ($MgCO_3$)	.67	Tr.	Tr.
Water	.67	.82	1.06

1. Two and one-half miles east of Scooba.
2. Seven miles east of Sucarnochee.
3. One and one-half miles south of Wahalak.

*Bull. 283, U. S. Geol. Survey, p. 216.

†Bull. 243, U. S. Geological Survey, pp. 206 to 219.

AVAILABLE CLAYS IN AND ADJACENT TO THE SELMA AREA.

As above stated, a mixture of clay with a pure limestone is necessary in the manufacture of Portland cement. The amount of clay varies with the amount of lime carbonate in the limestone. A pure limestone like that from Prairie Rock (see page 52) requires about one part of clay to two parts of limestone, while the limestone from near Wahalak requires the addition of a purer limestone.

There are two possible sources of clay for Portland cement in the Selma area and adjacent to it. These are (*a*) residual Selma clays; (*b*) Porter's Creek clay.

Residual Selma Clays.

Highly plastic clays, resulting from the decomposition of the Selma limestone, occur to greater or less extent over the entire Selma area. Where disintegration is complete the residual Selma clays are low in lime carbonate and comparatively high in alumina and silica. In the absence of any other clays they may be used with the limestones in making cement. In fact, the Alabama Portland cement plant at Demopolis, Alabama, uses the residual clay which occurs along Tombigbee River. The limestone used at this plant is comparatively low in lime carbonate and, therefore, requires only a small amount of clay to reduce the lime to the proper percentage.

TABLE 28.

ANALYSES OF SELMA LIMESTONE USED AT THE ALABAMA PORTLAND CEMENT PLANT, DEMOPOLIS, ALABAMA.

	1	2
Silica (SiO_2)	12.50	9.88
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	2.76	6.20
Lime carbonate ($CaCO_3$)	80.71	77.12
Magnesium carbonate (MgO)	1.05	1.08
Sulphur trioxide (SO_3)	1.62	n. d.
Water	1.36	5.72

1. R. S. Hodges, analyst.
2. Sen. Doc. No. 19, 58th Congress, 1st Session, p. 22.

No analysis of the clay used at the above mentioned plant is available. The following is an analysis of the residual Selma clay from Uniontown, Alabama:

TABLE 29.

ANALYSIS OF RESIDUAL CLAY FROM UNIONTOWN, ALABAMA.

(R. S. Hodges, Analyst.)

Silica (SiO_2)	69.57
Alumina (Al_2O_3) } Iron oxide (Fe_2O_3) }	19.04
Lime (CaO)	0.37
Ignition	9.68

TABLE 30.

ANALYSES OF RESIDUAL SELMA CLAYS FROM MISSISSIPPI.

	1	2	3	4	5	6	7
Silica (SiO_2)	63.63	75.95	72.32	65.30	56.97	63.35	67.60
Alumina (Al_2O_3)	10.34	9.62	8.74	12.63	15.09	13.70	12.55
Iron oxide (Fe_2O_3)	8.25	5.08	7.44	12.18	10.40	7.90	7.60
Lime (CaO)	3.75	1.25	1.55	1.50	1.00	0.80	.80
Magnesia (MgO)	.50	.74	.47	.63	0.54	0.60	.78
Volatile matter (CO_2)	7.77	2.52	5.58	2.27	10.90	6.50	5.00
Sulphur trioxide (SO_3)	.34	.34	.51	0.25	0.34	0.34	.17
Moisture	4.25	3.50	3.45	4.75	2.95	6.02	5.50

1. West Point.
2. West Point.
3. West Point.
4. Starkville.
5. Agricultural College.
6. Agricultural College.
7. Agricultural College.

Porter's Creek Clay.

Immediately above the Selma limestone, south of Houston, the Porter's Creek clay outcrops in a belt 2 to 15 miles wide. North of Houston the Ripley and Clayton limestones intervene between the Selma and the Porter's Creek formations. It is known as the "Flatwoods" country, and in places is characterized by low flat land resembling the broad bottom of a large river. The Porter's Creek clay is a dark gray clay which has a tendency to break into rectangular blocks when exposed to the sun. It contains small flakes of mica, which in places have been segregated into small dikes.

Excellent exposures of the Porter's Creek formation occur throughout the State where the Lafayette has been removed. The Mobile, Jackson and Kansas City Railway has made deep cuts into the clay at Walnut, Ripley, and along the divide between Houston and Maben. The Southern Railway, from West Point to Winona, cuts into the Porter's Creek in the hills between Maben and Pheba.

A sample of the residual Porter's Creek from 1 mile west of Starkville was analyzed with the following results:

TABLE 31.

ANALYSIS OF RESIDUAL PORTER'S CREEK CLAY, FROM 1 MILE WEST OF STARKVILLE.

Silica (SiO_2)	75.60
Alumina (Al_2O_3)	7.00
Iron oxide (Fe_2O_3)	8.24
Lime (CaO)	1.20
Magnesia (MgO)	.67
Volatile matter (CO_2)	3.91
Sulphur trioxide (SO_3)	.25
Moisture	2.97

The following analyses of the Porter's Creek clays were made from different localities in the State:

TABLE 32.

ANALYSES OF PORTER'S CREEK CLAY.

	1	2	3
Silica, (SiO_2)	57.25	71.47	61.62
Alumina (Al_2O_3)	6.17	9.45	8.87
Iron oxide (Fe_2O_3)	18.95	6.97	16.29
Lime (CaO)	1.05	.40	.91
Magnesia (MgO)	.95	.63	.69
Volatile matter (CO_2)	7.75	5.04	7.77
Sulphur trioxide (SO_3)	.21	.13	.28
Moisture	7.59	5.65	4.50

1. Residual clay from near Macon.
2. Residual clay from Wahalak.
3. Porter's Creek clay from Winston County.

The Illinois Central Railway from Starkville to Ackerman crosses the Porter's Creek formation, showing deep cuts of laminated grayish clay.

Again, on the Mobile and Ohio Railway, between Scooba and Lauderdale, occurs the same characteristic clay which has been traced across Alabama, Mississippi, western Tennessee and Kentucky.

A sample of the Porter's Creek clay from the town of Scooba was analyzed in the laboratory of the U. S. Geological Survey* with the following results:

TABLE 33.

ANALYSIS OF PORTER'S CREEK CLAY FROM SCOOBA.

(W. S. McNeil, Analyst.)

Silica (SiO_2)	61.92
Alumina (Al_2O_3)	19.47
Iron oxide (Fe_2O_3)	2.81
Magnesia (MgO)	1.98
Soda (Na_2O)	.50
Loss on ignition	12.29

*Geology and Mineral Resources of Miss., U. S. Geol. Survey, Bull. No. 283, p. 55.

It will be seen from the above analyses that the Porter's Creek clay is an excellent quality of clay for use in making cement.

JACKSON FORMATION.

Heretofore no attention has ever been paid to the calcareous marls of the Jackson formation for Portland cement. During the course of the present survey, experiments have been made using the marl for cement. Samples were collected from two of the most important places where the marl comes to the surface, and analyzed. The formation was so called from the typical exposures in the bank of Pearl River at Jackson. It underlies a large area of central Mississippi, just north of the Vicksburg limestone area. It comprises what is known as the "central prairie" region. The marl outcrops in comparatively few places owing to the overlying surface formations and residual soil. The surface of the country is not so broken as the region to the north and also to the south.

The materials composing the formation are principally calcareous, clayey marls, and unconsolidated limestones, clays and sands. The sandy portion is confined to about the uppermost 50 feet of the formation. The remaining 300 feet are marls and clays. The marls are easily recognized by the great amount of shells which they contain.

Throughout the entire Jackson area where the marls are near the surface they have undergone a chemical change. In the two analyses of Table 34a the nature of the change is apparent. No. 1 is an analysis of a partly weathered Jackson marl; No. 2 is the analysis of the clay derived from the marl. There has been a loss of lime carbonate in the marl and a porportionate gain of silicon dioxide and aluminum oxide in the clay. These changes have been brought about by weathering. The weathering of the marl, therefore, accounts for the presence of the green plastic clay which is found over the entire Jackson area from which the overlying Lafayette and yellow loam have been removed.

DISTRIBUTION.

Yazoo City.—Perhaps the best exposure of the Jackson calcareous marls in the State is found in the bluff at Yazoo City. This formation is exposed in the bluff for a distance of about 10 to 12 miles north and 15 miles south of the city. The following is a section of the bluff at the city reservoir:

Section of the Bluff at Yazoo City.

	Feet
Yellow loam brick clay	10–12
Gray calcareous Loess, which stands in perpendicular walls	100
Lafayette pebbles	12
Jackson marls, containing Zeuglodon bones and other Jackson fossils	180

A sample of the marl taken from this place was analyzed with the following results:

TABLE 34.

ANALYSIS OF JACKSON MARL-CLAY, YAZOO CITY.

Silica (SiO_2)	40.90
Alumina (Al_2O_3)	13.50
Iron oxide (Fe_2O_3)	5.55
Lime (CaO)	14.62
Magnesia (MgO)	.88
Volatile matter (CO_2)	19.25
Moisture	4.00

The above analysis was made from the surface and represents the transitional stage between the more highly calcareous marl and the plastic residual clay.

Jackson.—The Jackson marls are exposed in the bank of Pearl River between the wagon bridge and the Alabama and Vicksburg Railroad bridge. A continuation of the exposure is found extending up Town Creek. Other exposures are found in the bed of Moody's Branch near the city waterworks' stand-pipe, and in the railway cut ¼ mile north of the Asylum station. The Jackson clays, underlain by calcareous marls, are found in the deep cut on the Illinois Central Railway 1 mile south of Jackson. At the latter place the marl weathers to a slightly pinkish clay, which possesses a jointed structure. The clay contains in places small patches of very fine sand. The quality of the unweathered marl and the clay from this place is shown in the following analyses:

TABLE 34a.

ANALYSES OF JACKSON MARL AND CLAY 1 MILE SOUTH OF JACKSON.

	1	2
Silica (SiO_2)	35.72	59.82
Alumina (Al_2O_3)	13.79	12.24
Iron oxide (Fe_2O_3)	5.38	6.10
Lime (CaO)	17.00	2.90
Magnesium oxide (MgO)	1.99	1.68
Sulphur trioxide (SO_3)	0.12	2.11
Volatile matter (CO_2)	17.91	7.55
Moisture	5.85	6.08

VICKSBURG FORMATION.

The Vicksburg formation outcrops in a narrow belt of territory in Mississippi from 1 to 12 miles wide, extending across the State in an approximately northwest, southeast direction. The accompanying geological map of the State shows the area underlain by the Vicksburg and its relation to the Jackson marls on the north and the Grand Gulf group on the south.

The Vicksburg and the Jackson in Mississippi are mapped as two distinct formations, while in Alabama they are described together under the term St. Steven's limestone. The Vicksburg is the equivalent of the upper, and the Jackson of the lower part of the St. Steven's limestone.

The character and composition of the St. Steven's limestone has been described by Dr. E. A. Smith in Bulletin No. 243, pp. 77–81, U. S. Geological Survey. The large number of analyses of this limestone made in the laboratory of the Alabama Survey shows that it is well adapted to the manufacture of Portland cement. It carries from 75 to 95 per cent of calcium carbonate, with very little magnesium carbonate.

In Mississippi the Vicksburg formation includes thin beds of fine grained non-magnesium limestone from 1 to 4 feet thick, alternating with highly calcareous marl beds more or less indurated in places and bearing a rich fauna of Oligocene age. Some of the ledges of limestone make excellent building stone and lime, but owing to the great amount of interbedded marl and surface material, quarrying the limestone has been found to be unprofitable.

The alternating nature of the limestone and marl is shown in the following section of the bluff at Vicksburg,* between the city and the National Cemetery:

Section of the Bluff in Vicksburg.	*Inches*
22. First stratum of limestone from top, overlain by Loess.	10
21. Gray to yellowish marl	9
20. Heavy-bedded limestone	46
19. Indurated marl	34
18. Thin, calcareous, plastic clay	2
17. Indurated marl	6
16. Clay similar to No. 10	2
15. Indurated marl	5

*Bull. 283, U. S. Geol. Survey, p. 38.

Section of the Bluff in Vicksburg—Continued.

	Inches
14. Clay	4
13. Hard limestone	18
12. Clay and marl from ½ to 2 inches thick	15
11. Indurated marl	21
10. Limestone	18
9. Gray marl	18
8. Limestone	18
7. Marl	3–6
6. Hard limestones	52
5. Marl	6
4. Limestone	27
3. Marl	17
2. Limestone	20
1. Marl	45

In the above section there are 17 feet and 5 inches of hard limestone, and 16 feet and 8 inches of marl and clay. The impracticability of using the hard limestone without using the marl and the clay is at once apparent. One of the special features in the study of this formation has been to determine the possibility of utilizing the marls in combination with the limestone in the manufacture of Portland cement.

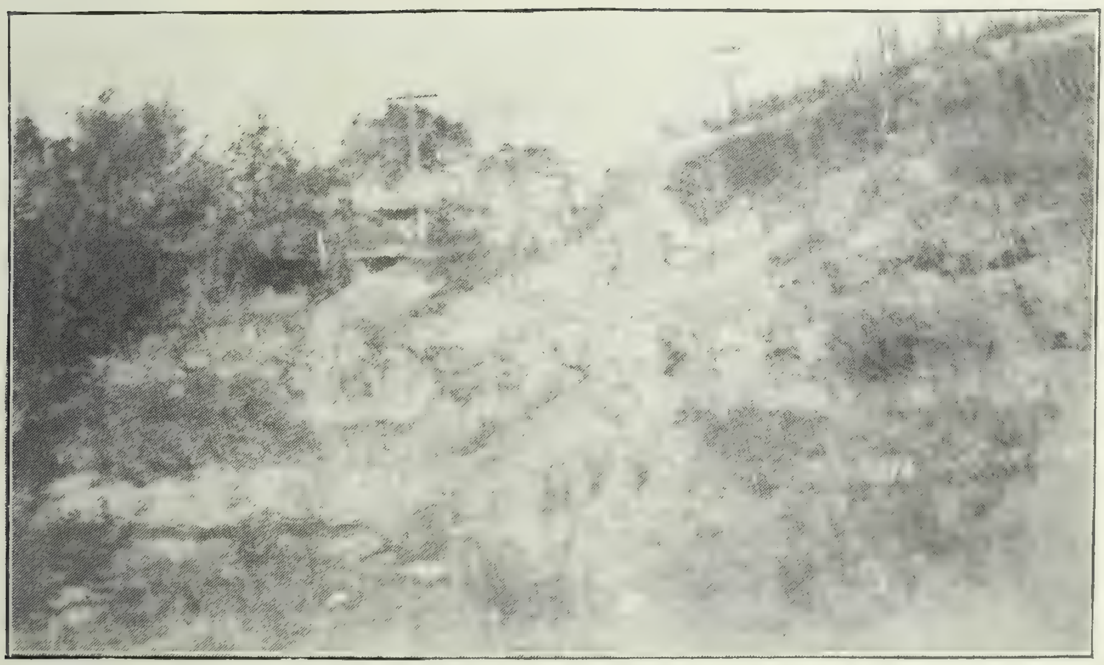
A large number of analyses of the marls from different localities show that they contain no large amounts of injurious properties, and can be used for cement as they come from the quarry. The marls and the clays supply the silica and alumina for Portland cement and are therefore of equal value to the limestone. In fact, by taking a general average of the analyses of the limestones and the interbedded marls we obtain the desired mixture for a Portland cement, without the addition of other materials.

In the central and the eastern parts of the State the Vicksburg formation is more homogeneous than it is in the western area. In Smith County the Vicksburg is a soft porous limestone which is known as the "chimney rock." It is quarried for chimneys and foundation pillars by sawing it into any desired shape with a large saw. On exposure to the air it hardens and lasts for 30 to 40 years. The "chimney rock" is one of the purest forms of the Vicksburg limestone.

DISTRIBUTION.

Vicksburg.—The typical locality of the Vicksburg formation is in the bluff in and near the city of Vicksburg. In the bluff overlooking

Plate III.



BLUFF AT VICKSBURG SHOWING VICKSBURG LIMESTONE.
(Photo by W. N. Logan.)

the Mississippi River just below the oil mill, ½ mile south of the confluence of the Yazoo and the Mississippi rivers, the following exposure of the Vicksburg formation was observed. The limestone outcrops on the river for a distance of 800 feet. On the slope facing the river between the oil mill and the city the limestone underlies a thin veneer of soil. It is exposed in the branches and in a few places along the track of the Yazoo and Mississippi Valley Railway from the oil mill to the National Cemetery. The top of the Vicksburg forms a bench-like terrace which extends back to the foot of the Loess bluff.

Section of Vicksburg Limestone at the Oil Mill, 2½ Miles South of Vicksburg.

	Feet
9. Loess in the bluff back from the river	100
8. Marl	2
7. Ledge of hard limestone	3
6. Bed of soft marl	3
5. Ledge of limestone	5
4. Marl stratum	5
3. Ledge of hard limestone	5
2. Hard limestone	3
1. Bed of compact marl	5
Water's edge.	

The thickness of the exposure in the above section is about one-third of the entire thickness of the Vicksburg formation.

Analysis of each stratum from Nos. 1 to 7 inclusive was made with the following results. The numbers of the analyses correspond to the numbers in the above section.

TABLE 35.

ANALYSES OF VICKSBURG LIMESTONE AND MARLS FROM VICKSBURG.

	1	2	3	4	5	6	7	*Average*	8
Silica (SiO_2)	32.45	6.43	7.39	25.27	5.58	13.62	3.10	13.41	7.08
Alumina (Al_2O_3)	2.12	.31	1.02	4.50	1.00	3.00	.25	1.74	.61
Iron oxide (Fe_2O_3)	2.05	2.00	2.48	5.37	2.18	2.75	1.62	2.63	2.50
Lime (CaO)	34.20	50.25	47.50	29.50	49.97	40.37	50.63	43.20	50.44
Volatile matter (CO_2)	26.65	39.00	38.65	24.10	39.26	33.66	41.00	34.62	37.22
Magnesium oxide (MgO)	.38	1.36	1.45	1.99	1.01	1.72	.99	1.29	1.07
Sulphur trioxide (SO_3)	.08	.36	.51	2.76	.30	.98	.60	.79	0.38
Moisture	1.60	.61	1.10	3.95	.82	2.75	.60	1.63	0.40

No. 8 is a limestone from Steel's Bayou, Vicksburg.

A small fragment of limestone from each ledge including Nos. 2, 3, 5 and 7 was pulverized and the mixture analyzed with the results given in No. 1 below. A similar analysis was made from a mixture of the marls with the results given in No. 2.

TABLE 36.

ANALYSES OF VICKSBURG LIMESTONE AND MARLS FROM VICKSBURG.

(Dr. A. M. Muckenfuss, Analyst.)

<table>
<tr><th></th><th>1</th><th>2</th><th>Average</th></tr>
<tr><td>Silica (SiO_2)</td><td>4.95</td><td>24.97</td><td>14.96</td></tr>
<tr><td>Alumina (Al_2O_3)</td><td>.56</td><td>6.49</td><td rowspan="2">5.46</td></tr>
<tr><td>Iron oxide (Fe_2O_3)</td><td>2.47</td><td>1.36</td></tr>
<tr><td>Lime (CaO)</td><td>50.11</td><td>33.97</td><td>42.04</td></tr>
<tr><td>Carbon dioxide (CO_2)</td><td>39.30</td><td>26.38</td><td>32.84</td></tr>
<tr><td>Magnesia (MgO)</td><td>1.13</td><td>1.60</td><td>1.37</td></tr>
<tr><td>Alkali (K_2O)</td><td>0.15</td><td>0.70</td><td>.43</td></tr>
<tr><td>Sulphuric acid (SO_3)</td><td>0.25</td><td>1.00</td><td>.63</td></tr>
<tr><td>Phosphoric acid (P_2O_5)</td><td>0.03</td><td>0.07</td><td>.06</td></tr>
<tr><td>Insoluble matter, volatile (organic)</td><td>0.84</td><td>2.24</td><td>1.54</td></tr>
<tr><td>Moisture</td><td>0.20</td><td>0.82</td><td>.51</td></tr>
</table>

The value of the Vicksburg limestone as a Portland cement rock is shown by comparing the general average of the above analyses to the analyses of actual cement mixtures given in the following table. The amount of combined impurities in the Vicksburg limestone is smaller than that in the actual mixtures given below:

TABLE 37.

COMPOSITION OF ACTUAL MIXES USED IN AMERICAN CEMENT PLANTS

<table>
<tr><td>Silica (SiO_2)</td><td>14.77</td><td>12.85</td><td>15.18</td><td>11.8</td><td>13.52</td><td>13.46</td><td>13.85</td><td>12.62</td><td>14.94</td><td>12.92</td></tr>
<tr><td>Alumina (Al_2O_3)</td><td rowspan="2">4.35</td><td>4.92</td><td rowspan="2">6.42</td><td rowspan="2">8.2</td><td rowspan="2">6.56</td><td rowspan="2">n.d.</td><td rowspan="2">7.20</td><td rowspan="2">6.00</td><td>2.66</td><td>4.83</td></tr>
<tr><td>Iron oxide (Fe_2O_3)</td><td>1.21</td><td>1.10</td><td>1.77</td></tr>
<tr><td>Lime (CaO)</td><td>43.03</td><td>42.76</td><td>42.97</td><td>41.8</td><td>42.07</td><td>41.25</td><td>41.40</td><td>42.26</td><td>42.34</td><td>42.30</td></tr>
<tr><td>Magnesia (MgO)</td><td>1.74</td><td>1.02</td><td>n.d.</td><td>0.8</td><td>2.07</td><td>n.d.</td><td>n.d.</td><td>2.67</td><td>2.21</td><td>2.08</td></tr>
<tr><td>Carbon dioxide (CO_2)</td><td>35.61</td><td>34.71</td><td>n.d.</td><td>n.d.</td><td>35.31</td><td rowspan="2">34.86</td><td rowspan="2">36.42</td><td>36.10</td><td>35.68</td><td>35.49</td></tr>
<tr><td>Water</td><td>n.d.</td><td>n.d.</td><td>n.d.</td><td>n.d.</td><td>n.d.</td><td>n.d.</td><td>n.d.</td><td>n.d.</td></tr>
</table>

The Vicksburg outcrops at intervals in the bluff from the city of Vicksburg to the town of Redwood or beyond; the limestone occurs beneath a thick Lafayette and Loess overburden which attains a maximum thickness of about 175 feet.

In the hills south of Vicksburg the Grand Gulf clays are found on the hillsides and in the bluffs beneath the Loess and Lafayette. In places it is a highly plastic gray clay interbedded with aluminous sandstone. From five miles south of Vicksburg, on the old Roche land, a sample of Grand Gulf clay was analyzed with the following results*:

ANALYSIS OF CLAY 5 MILES SOUTH OF VICKSBURG.

Silica (SiO_2)	58.50
Alumina (Al_2O_3)	19.04
Ferric oxide (Fe_2O_3)	1.93
Lime (CaO)	1.48
Magnesia (MgO)	1.66
Sulphur trioxide (SO_3)	Trace
Moisture	3.19
Loss on ignition	8.26

*Bull. 283, U. S. Geol. Survey, p. 68

Plate IV.

LEDGE OF VICKSBURG LIMESTONE, CLINTON.

Byram.—The Vicksburg formation outcrops in the hills northwest of Byram. One mile north of the station the rock is exposed in the railway cut. From the little hill to the west of this exposure the hard limestone was used formerly for making lime.

Hard ledges of limestone interbedded with beds of indurated marl are exposed in the banks of Pearl River from about ¼ of a mile below to 2½ miles above Byram. In places the same ledge may be seen in the bank of the river only a few feet above the water for a distance of ½ mile. There is a gentle fold in the rocks with the axis extending in an approximately east and west direction (see Plate V).

Samples of the limestone and marl from the bank of the river at Byram were analyzed with the following results:

TABLE 38.

ANALYSES OF VICKSBURG LIMESTONE AND MARL FROM BYRAM.

	Limestone	*Marl*
Silica (SiO_2)	2.28	26.42
Alumina (Al_2O_3)	2.42	8.25
Ferric oxide (Fe_2O_3)	2.19	5.20
Lime (CaO)	50.55	27.77
Magnesia (MgO)	1.40	1.44
Volatile matter (CO_2)	40.87	26.00
Sulphur trioxide (SO_3)	.30	2.00
Moisture	.31	3.00

About 2½ miles north of Byram on the east bank of Pearl River the following section is exposed:

*Section of Vicksburg Formation 2½ Miles North of Byram.**

	Inches
Gray rotten limestone containing grains of glauconitic sand	24
Harder gray limestone	24
Indurated brown marl	24
Hard, compact, gray limestone	16
Soft yellow marl	14
Very hard gray limestone	10
Gray marly clay	8
Compact limestone	20
Indurated white to gray marl	20
Ferruginated sandy limestone	72
Green-sand marl base of exposure	60

Plain.—The Vicksburg limestone outcrops in the first cut south of Plain, on the Gulf and Ship Island Railway. The exposure here as at

*Unpublished notes obtained by the writer while employed on the U. S. Geol. Survey.

Vicksburg is composed of alternating beds of limestone and marl. At the top of the formation is a plastic, calcareous red clay, which is formed from the decomposition of the limestone and the marl. Samples of each stratum in the cut were analyzed with the following results:

TABLE 39.

ANALYSES OF VICKSBURG LIMESTONE AND MARLS FROM NEAR PLAIN.

							Average
Silica (SiO_2)	7.57	1.85	4.95	12.52	14.11	17.53	9.76
Alumina (Al_2O_3)	1.23	1.37	0.00	4.75	2.87	1.42	1.94
Iron oxide (Fe_2O_3)	5.50	1.75	4.25	5.50	6.60	15.15	6.46
Lime oxide (CaO)	46.33	52.12	47.50	39.75	39.78	29.87	42.56
Magnesium oxide (MgO)	0.02	0.49	1.16	0.81	0.40	0.02	.48
Volatile matter (CO_2)	38.54	41.87	39.25	34.50	34.33	27.45	35.99
Sulphur trioxide (SO_3)	.09	.....	.25	.....	.17	.....	.17
Moisture	.27	.25	1.25	1.56	1.62	5.25	1.70

The Vicksburg limestone can be easily traced by the outcrops in the hills from the exposure in the railway cut south of Plain westward to Pearl River, and eastward to Brandon. At no place is there a great thickness exposed, rarely more than 20 feet, and frequently much less.

Brandon.—The Vicksburg limestone is exposed at the railway station at Brandon and for ¼ mile to the west. Another exposure is found at the old Yost lime kiln site, 1 mile east of the station.

The most complete exposure of the Vicksburg, east of Pearl River, is found at the old Robinson quarry, about 4 miles southeast of Brandon. The formation is made up of hard ledges of crystalline limestone alternating with beds of calcareous marl of about equal thickness. This rock was quarried for some time by a firm in Jackson. It was crushed and used in the foundation of the new State Capitol. Work was discontinued because of the great amount of useless marl which had to be removed to get the rock. The analyses as given below show that the marl and limestone could all be used in making Portland cement.

This material is easily quarried as there is little or no superincumbent matter. A spur from the main line of the Alabama and Vicksburg Railway has been built from Rankin to the quarry, thus giving an easy outlet for the material.

Plate V.

VICKSBURG LIMESTONE ON PEARL RIVER, BYRAM.

TABLE 40.

ANALYSES OF VICKSBURG LIMESTONE FROM ROBINSON QUARRY, 4 MILES SOUTHEAST OF BRANDON.

Silica (SiO_2)	4.22	4.55	5.56	1.58	16.88
Alumina (Al_2O_3)	.75	.00	1.09	4.40	5.70
Iron oxide (Fe_2O_3)	4.37	4.25	4.01	3.31	3.59
Lime oxide (CaO)	49.62	49.92	48.44	48.40	36.86
Magnesium oxide (MgO)	.09	.09	.78	1.27	.99
Volatile matter (CO_2)	40.05	39.61	38.12	39.70	33.16
Sulphur trioxide (SO_3)	.36	.72	.24	.45	.24
Moisture	.88	.95	1.61	.60	2.10

Bay Spring.—There are numerous outcrops of the Vicksburg formation between Brandon and Bay Spring, but as they are so far removed from lines of transportation it is hardly possible that the limestone will soon become of value for cement, and consequently only one of the most important outcrops will be described in this report.

On the east side of Tallahala Creek, about 4 miles west of Bay Spring, the Vicksburg limestone outcrops in the road and on the side of the hill. Above the limestone is a pink, plastic clay very similar to the clay overlying the limestone 1⅓ miles south of Plain (see preceding page). The thickness of the Vicksburg here is 65 feet.

The uppermost member of the Vicksburg is a ledge of hard bluish gray limestone, which is so much more resistant than the overlying Grand Gulf clay that it forms a marked bench along the hillside at this place. One thing noticeable about the Vicksburg limestone at this locality is the absence of marl beds alternating with harder ledges of limestone. The top of the formation is capped with a hard ledge of limestone, but all the material underneath this to the bottom of the hill is a soft, porous, white to yellowish limestone. The harder ledges of limestone were formerly used for burning lime.

On Mr. Houston's land, 2 miles west of Sylvarina, is a quarry where the soft, porous limestone is sawed out for building chimneys. The rock for 3 to 4 feet below the surface has disintegrated into a rotten mass, easily picked to pieces with a spade. Below this it is sufficiently compact to be used for building chimneys. The quarry has been worked for 17 years.

Chimneys built of this rock first disintegrate at the top. The rock is very porous; it fills with water which freezes in the winter and causes it to break. The rock has also been used for making lime and

doubtless is very desirable for this purpose, since it is almost pure lime carbonate.

No detailed work has been done on the Vicksburg limestone by the present survey along the New Orleans and Northeastern, and the Mobile and Ohio railways. The hard upper ledges outcrop in the hills north and east of the town of Vossburg.

Two samples of limestone from near Nancy, Clarke County, were collected by W. N. Logan, and analyzed with the following result:

TABLE 41.

ANALYSES OF VICKSBURG LIMESTONE FROM NEAR NANCY, CLARKE COUNTY.

Silica (SiO_2)	7.31	6.77
Alumina (Al_2O_3)	13.61	4.68
Iron oxide (Fe_2O_3)	4.00	2.00
Lime oxide (CaO)	36.62	45.51
Magnesia (MgO)	.29	.64
Volatile matter (CO_2)	35.20	35.40
Sulphur trioxide (SO_3)	2.78	3.00
Moisture	1.00	1.79

"Near Red Hill,* in Wayne County, on Limestone Creek, the Mobile and Ohio Railway is cut through a considerable hill, where the limestone group of the Eocene formation is well exhibited. Limestone Creek, which runs south of the cut on the railroad and empties about 400 yards from it, into the Chickasawhay River, contains large ledges of hard, compact limestone; and southeast of the cut about $1\frac{1}{2}$ miles the sandstone which appears south of the cut and not well cemented, crops out as a hard limestone, an excellent material for building purposes."

At the confluence of Limestone Creek and Chickasawhay River Dr. Harper gives the following section of the limestone:

Section of Vicksburg Limestone at the Mouth of Limestone Creek, Wayne County.

Surface soil, chiefly sand	—
Yellowish limestone	—
Calcareous sand containing Pecten	—
Calcareous marl containing Orbitoides, Ostrea, Pecten, Arca, Flabellum, Cardita, etc	—
Shell marl	—

No thicknesses are given.

Three analyses of the limestone from Red Hill, Wayne County, are given by Dr. L. Harper (†) as follows:

*Geology and Agriculture of Mississippi, 1857, L. Harper, p. 140.

†Ibid, p. 166.

PLATE VI.

VICKSBURG LIMESTONE, ROBINSON QUARRY, NEAR RANKIN.
(Photo by W. N. Logan.)

TABLE 42.

ANALYSES OF VICKSBURG LIMESTONE FROM RED HILL, WAYNE COUNTY.

(Dr. L. Harper, Analyst.)

Silica (SiO_2)	6.30	15.05	9.20
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	7.20	5.35	6.65
Lime (CaO)	48.44	44.58	47.12
Carbon dioxide (CO_2)	38.06	35.02	37.03
Water	n. d.	n. d.	n. d.

Dr. E. W. Hilgard (*), in speaking of the occurrence of the Vicksburg limestone in Wayne County, says: "On the Chickasawhay, between Red Bluff and the latitude of Waynesboro, both marls and limestones crop out with frequency; the same is the case on the creeks on the east side as on Cakchey's Mill Creek and Limestone Creek, especially near the mouth of the latter, at the foot of the hill on which Dr. E. A. Miller lives—the most southerly outcrop of the calcareous Vicksburg on the Chickasawhay. The sections exhibited here in the river banks and cuts of the railroad correspond so closely to those between Yost's lime kiln and Brandon depot that the specimens can hardly be distinguished from each other when placed side by side, the only difference being the great abundance of Orbitoides in the soft white marl intervening between the strata of rock. The ledges of hard limestone (in Wayne County) are not so well defined—the rock being softer and whitish."

(*)Geology of Mississippi, Hilgard 1860, p. 146

ADVANTAGEOUS LOCATIONS FOR CEMENT PLANTS.

To build a Portland cement plant at a point remote from transportation lines is to invite financial loss. And under the present system of levying freight rates it is almost equally perilous to build a plant where there is but one transportation outlet, unless satisfactory arrangements have been made previous to the erection of the plant.

In Mississippi there are four general localities where raw materials, and good transportation facilities can be obtained.

TISHOMINGO COUNTY.

The Southern Railway from Memphis to Chattanooga passes near the northern outcrop of the oolitic limestone in Tishomingo County near where the road crosses Bear Creek. At this point it is only 8 miles to the Tennessee River. The largest boats of that river run as far as the mouth of Bear Creek. A cement plant built at this point would have an outlet to the north by boat and a railway connection to the east, west and south. Coal could be obtained by river or from the nearby Alabama fields at a minimum cost. A Portland cement plant at Mingo bridge could use the oolitic limestone and the overlying shale. Bear Creek furnishes sufficient water to run a mill by water power. The newly constructed line of the Illinois Central Railway connecting Birmingham, Alabama, and Jackson, Tennessee, with an outlet to the north and south, runs within 3 miles of this place.

STARKVILLE AND WEST POINT.

The Selma limestone and Porter's Creek clay are in proximity along the Mobile and Ohio Railway in Kemper County, along the Illinois Central in Oktibbeha County, and along the Southern in southern Clay County. The relations of these locations to transportation lines are clearly indicated on the map. The Mobile and Ohio furnishes an outlet to the north and south. The Southern line from

Greenville, Mississippi, to Birmingham, Alabama, offers an outlet to the east and west. The Aberdeen branch of the Illinois Central connects with the main line from Louisville to New Orleans at Durant, thus giving an outlet into a new territory.

Starkville and West Point offer exceptional advantages for Portland cement plants, inasmuch as limestone and clay are found near in great abundance, and the coal field of Alabama is less than 100 miles away. In fact either of these places is closer to the coal field by rail than the Alabama Portland Cement plant at Demopolis.

With a bed of limestone 800 to 1,000 feet thick underlying Noxubee, Clay, Lee, eastern Oktibbeha and Chickasaw counties, and an inexhaustible supply of clay just west of the Selma area, there is a sufficient amount of raw material to supply the Portland cement trade of the entire United States for an indefinite length of time.

Starkville and West Point afford good advantages in regard to proximity of raw material and fuel for a cement plant; and they have a fair outlet for the finished product.

COLUMBUS.

The town of Columbus has plenty of limestone near and has some advantages over West Point and Starkville in being closer to the coal field of Alabama. With the opening of the Tombigbee River to navigation cheaper rates could be had than at any other city in eastern Mississippi. Good clays can be obtained in the Tuscaloosa and the Eutaw formations in the hills east of Tombigbee River.

JACKSON AND VICINITY.

The Vicksburg limestone outcrops in the banks of Pearl River at Bryam, in the railway cut 1½ miles south of Plain, and again at the Robinson quarry near Rankin. All of these outcrops are on railway lines and within a radius of 14 miles from Jackson. The limestones at all of these places have been analyzed and found to be desirable materials for Portland cement. Jackson is a good distributing point with seven railway lines radiating to the north, east, south and west. Two railway lines, the Illinois Central and the Gulf and Ship Island, connect Jackson with deep water routes to the Gulf.

VICKSBURG.

Vicksburg offers more natural advantages for the location of a cement plant than any other city in the State. Raw material of limestone and marl are found in the bluffs facing the river. The Mississippi River and the Yazoo and Mississippi Valley Railway afford transportation to the north and south; the Alabama and Vicksburg Railway affords transportation to the east and west. Coal could be obtained by river from Pittsburg, by the Yazoo and Mississippi Valley Railway from Illinois and western Kentucky, and by the Alabama and Vicksburg Railway from the Alabama coal field.

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Mississippi State Geological Survey

ALBERT F. CRIDER, DIRECTOR.

BULLETIN No. 2

CLAYS OF MISSISSIPPI

PART I.

Brick Clays and Clay Industry of Northern Mississippi

By WILLIAM N. LOGAN

BRANDON-NASHVILLE

STATE GEOLOGICAL COMMISSION.

HIS EXCELLENCY, JAMES K. VARDAMAN .... *Governor*
DUNBAR ROWLAND .... *Director of Archives and History*
A. A. KINCANNON .... *Chancellor of the State University*
J. C. HARDY .... *President Agricultural and Mechanical College*
JOE N. POWERS .... *State Superintendent of Education*

GEOLOGICAL CORPS.

ALBERT F. CRIDER .... *Director*
DR. WILLIAM N. LOGAN .... *Assistant Geologist*
DR. CALVIN S. BROWN .... *Assistant Geologist*

LETTER OF TRANSMITTAL.

STATE GEOLOGICAL SURVEY.

JACKSON, MISSISSIPPI, July 20, 1907.

To Governor James K. Vardaman, Chairman, and Members of the Geological Commission:

GENTLEMEN—I submit herewith a report on the clays and clay industry of northern Mississippi by Dr. William N. Logan, and respectfully recommend its publication.

Very respectfully,

ALBERT F. CRIDER,

Director.

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CHAPTER I.

ORIGIN AND CLASSIFICATION OF CLAY.

POSITION AND RELATION OF CLAY TO OTHER EARTH MATERIALS.

Structurally the known and knowable portion of the earth may be divided into three great spherical envelopes. An outer gaseous sphere, the atmosphere; a liquid sphere, the water sphere or hydrosphere; and a solid rock sphere called the lithosphere.

LITHOSPHERE.

The lithosphere consists of a loose mantle of earthy material, the regolith, at the surface and a more compact, indurated substratum, the durolith, to which the term "bed rock" is often applied.

Regolith.

The regolith consists of unconsolidated beds of sand, gravel, pebbles, bowlders and clay, or of mixtures of these together with organic matter forming loams, marls, peat, and soils. The regolith varies in thickness from a few inches to several hundred feet. It is often but the residual product resulting from the weathering of the bed rock. Its thickness, therefore, may represent the amount of bed-rock decay that has taken place at that point or it may represent the amount of decay which has taken place on some neighboring higher area, the debris of which has been transported to this point.

Durolith.

The durolith consists of beds of consolidated and more or less indurated rocks such as shale, sandstone, limestone, coal, granite and marble. In some regions the durolith is completely concealed by the regolith so that it may be studied only by means of deep cuts and the records of wells which pierce its strata. As to the thickness of the durolith we have little knowledge. The most profound excavations of Nature do not descend to depths much greater than one mile. The deepest excavations or borings made by man transcend this limit only by a small degree. Therefore, our knowledge of the thickness of the crust of the earth, as well as our knowledge of its internal mass, we gain only by inference.

Rocks of the Regolith.

The mantle rocks are unconsolidated fragments of rock waste and organic decay forming sand, clay, marl, loess, and gravels.

Sand.—Sand is composed of hard particles, usually of quartz, though sands of feldspar, magnetite, mica, gypsum and other minerals are not uncommon. Most quartzose sands contain at least small quantities of some of these minerals. The individual grains of sand may have sharp edges and irregular forms. These are generally particles which have not been eroded by transportation. Sharp sands are for the most part residual sands. Transported sands are more regular in form and have a rounded surface, or sub-angular edges. The size of the sand particles are extremely variable. They range from the coarseness of gravel to the impalpability of dust. In color there exists a multiplicity of tints and shades. In some sands the coloring matter is inherent; in many, however, it is due to the presence of an enclosing film of pigment such as oxide of iron.

Clay.—Clay is a soft rock which is usually smooth or greasy to the touch. When mixed with the proper proportion of water it may be readily molded into desired forms which will have the power of retaining their shape. This property, plasticity, is not possessed in a high degree by other rocks and is therefore one of the determinative characters of clay. Clay is a mechanical mixture of minerals. The proportion of these mineral constituents may vary; hence the composition of clays varies greatly. Aluminous clays are those containing a large quantity of the mineral kaolinite, which is the basis of all clays. Arenaceous clays contain a large quantity of sand. Calcareous clays contain much carbonate of lime. Ferruginous clays are those containing considerable proportion of some iron compound.

Loess.—Loess is a silty material composed of very fine particles of clay, sand, limestone and other earthy materials and also some organic matter. In cuts and excavations it tends to maintain vertical faces and a columnar structure. In many places it contains irregular concretions of calcium carbonate and the shells of species of gastropods.

Marl.—Marl is a mixture of clay, sand, and limy material. Shell marl is a mixture of clay, sand and the shells and bones of animals, such as snails, mussels, fish and oysters. Marls may be of marine

PLATE II.

ROADBED IN THE LOESS, NATCHEZ.

origin formed under sea water or they may be of lacustrine origin, formed in lakes.

Peat.—Peat is a dark substance composed mainly of vegetable matter which has undergone changes under water. It is formed by the accumulation of vegetable matter in lakes, ponds and marshes. Its amount of organic matter depends inversely upon the amount of earthy matter deposited with the vegetation.

Gravel, Pebbles and Bowlders.—Gravel, pebbles and bowlders are fragments of hard rocks of sizes varying from a pea in gravel and pebbles, to rounded fragments several feet in diameter in bowlders. Since this material can be transported only by streams of high velocity, these deposits are usually found where such streams suddenly lose their velocity. Mountain streams which descend to plains deposit such rocks.

Rocks of the Durolith.

The rocks of the durolith are more compact than those of the regolith. They may exist without planes of division or they may be formed of layers; in the former case they are said to be massive, in the latter to be stratified. Sandstone, shale, limestone, conglomerate, coal, granite, gneiss, marble and slate are some of the more common kinds of bed-rock.

Sandstone.—Sandstone is a rock formed of grains of sand bound together by some cementing substance. The cement may be iron, lime or silica. Coarse sandstones are composed of large sand grains. Where the grains are small the texture of the rock is fine. Sandstones may be massive or stratified. Crossbedded sandstones are those in which the bedding planes do not lie in parallel lines, but in which one set of planes lies oblique to another set. The color of sandstones is usually dependent on the presence of films of coloring matter coating the individual grains.

Conglomerate.—Conglomerate is formed by the cementation of gravel and pebbles. As in the case of sandstone, the cement may be iron, lime or silica. If the pebbles are rounded, the rock is called pudding stone; if the fragments are irregular or angular, the rock is called breccia. Such rocks may be deposited under the sea, in which case they may be identified as marine in origin by the organic remains usually found in them. Many beds of such rocks devoid of organic

remains are supposed to have been deposited in lodgement areas upon the land.

Shale.—Shale is compressed clay which has a form of cleavage causing it to split into flakes or blocks. Its physical properties are similar to those of clay, though it is usually harder and more dense. Shale is formed of clay which has been carried by the action of streams from the land and deposited either in the sea or in lakes. After deposition the clay is subjected to the pressure of overlying rocks, and to crustal movements which increase its density and develop its structure. Since the clay particles are smaller and lighter than other rock fragments, they are carried further out. The sorting action may result in beds of marked purity. The color of shales is generally dark or blue and is due to the presence of either some iron compound or of organic matter. The removal of the coloring matter by weathering usually results in lighter colors.

Limestone.—Limestone is composed, for the most part, of calcium carbonate derived from the skeletons of animals. All marine animals secreting either an endo-skeleton or an exo-skeleton may contribute to the formation of such beds. Deposits of coral form one of the chief sources of such lime material. Skeletons of shell-fish dropped within the littoral zone of the sea become broken and the fragments cemented together to form shell rock which by further changes may form compact limestones. Shells of animals of microscopic size form beds of chalk, sometimes of great extent and thickness.

Marble.—Marble is a metamorphic limestone of crystalline nature. Slate may have been formed likewise from the metamorphism of shale.

Granite.—Granite is a crystalline rock of igneous origin. It is composed mainly of varying amounts of feldspar, mica, quartz and hornblende, with very much smaller amounts of other minerals. The crystals are usually of microscopic size and closely interlocked. The color of the granite is largely dependent on the feldspar, which is usually either pink or gray. The disintegration and the decomposition of granite result in the formation of beds of sand and kaolin, the former being derived from the quartz and the latter from the feldspar. Wherever granite under the influence of metamorphic action has become foliated, it forms a rock termed gneiss.

Rocks are usually classed as: (1) fragmental rocks, those formed from the particles of older rocks; (2) igneous rocks, those formed from the cooling of molten magmas; (3) metamorphic rocks, those which have undergone alteration under the influence of heat and pressure.

Fragmental rocks, which are deposited under water, are called aqueous or sedimentary. Those deposited by wind are called eolian rocks. Limestone, sandstone and shale are common examples of fragmental rocks; granite, syenite and gabbro are examples of igneous rocks; while marble, slate and anthracite coal are examples of metamorphic rocks.

Classification of Rocks.

I. Fragmental rocks, also called aqueous or sedimentary, deposited by winds, water and ice on land and in water.

- A. Sand group.
  1. Sand.
  2. Gravel.
  3. Sandstone.
  4. Pudding-stone.
  5. Breccia.
- B. Lime group.
  1. Chalk.
  2. Coquina.
  3. Limestone.
  4. Dolomite.
  5. Marl.
  6. Travertine.
  7. Tufa.
- C. Clay group.
  1. Kaolin.
  2. Clay.
  3. Shale.
  4. Loam.
  5. Loess.
  6. Till.

- II. Igneous rocks, resulting from the solidification of molten magmas.
  - A. Pyroclastic rocks.
    - 1. Volcanic ash.
    - 2. Lapilli and bombs.
    - 3. Tuffs.
    - 4. Scoriae.
    - 5. Pumice.
    - 6. Puzzolana.
  - B. Lavas or glassy rock.
    - 1. Acidic.
      - *a*. Obsidian.
      - *b*. Perlite.
      - *c*. Trachyte.
      - *d*. Rhyolite.
    - 2. Basic.
      - *a*. Basalts.
      - *b*. Dolerite.
  - C. Phanerocrystalline rocks.
    - 1. Acidic.
      - *a*. Granite.
      - *b*. Syenite.
    - 2. Basic.
      - *a*. Gabbros.
      - *b*. Peridotites.
- III. Metamorphic rocks.
  - A. Rocks of sedimentary origin.
    - 1. Marble.
    - 2. Slate.
    - 3. Quartzite.
  - B. Rocks of igneous origin.
    - 1. Gneiss.
    - 2. Schist.

Composition of the Lithosphere.

The rocks of the lithosphere are composed of a large number of minerals, these minerals in turn being composed of elements. To

illustrate, calcite ($CaCO_3$), the principal constituent of limestone, is composed of three elements, calcium, carbon and oxygen. These are united in the proportion of one part calcium and one part carbon to three parts of oxygen. More than 70 chemical elements have been discovered in the earth. Eight of these elements form nearly 99 per cent of the solid crust of the earth.

The estimated composition of the solid portion of the lithosphere is given by F. W. Clarke* as follows:

TABLE 1.

COMPOSITION OF THE LITHOSPHERE.

Element	*Symbol*	*Per Cent in Crust*
1. Oxygen	(O)	47.02
2. Silicon	(Si)	28.06
3. Aluminum	(Al)	8.16
4. Iron	(Fe)	4.64
5. Calcium	(Ca)	3.50
6. Magnesium	(Mg)	2.62
7. Sodium	(Na)	2.63
8. Potassium	(K)	2.32
9. Titanium	(Ti)	.41
10. Hydrogen	(H)	.17
11. Carbon	(C)	.12
12. Phosphorus	(P)	.09
13. Manganese	(Mn)	.07
14. Sulphur	(S)	.07
15. Barium	(Ba)	.05
16. Strontium	(Sr)	.02
17. Chromium	(Cr)	.01
18. Nickel	(Ni)	.01
19. Lithium	(Li)	.01
20. Chlorine	(Cl)	.01
21. Fluorine	(Fl)	.01
Total		100.00

The last thirteen of these elements comprise only 1.05 per cent of the solid crust, while the precious metals such as gold and silver, and the baser metals such as copper, lead and zinc, constitute such a small percentage of the rocks as to be considered negligible quantities.

As already stated the elements are united to form minerals which make up the rocks of the lithosphere. Oxygen uniting with silicon produces an oxide (SiO_2) which acts as an acid. The acid uniting with bases such as aluminum, potassium and calcium forms silicates, and uniting with other elements it forms oxides of iron, calcium,

*Analysis of Rocks, Bul. 168, U. S. Geol. Survey, 1900, p. 15.

magnesium, etc. These by the union with acids produce sulphates, chlorides, carbonates and other combinations.

Rock Alteration and Decomposition.

The disintegration of rocks is brought about by the action of two sets of forces. The internal dynamical forces of the earth produced by the loss of heat and consequent shrinkage of the earth, result in faulting, folding, oscillation and deformation, accompanied by vulcanism and earthquakes. These movements disrupt the rocks and contribute to their decay.

The forces of the atmosphere, the hydrosphere and the life sphere are agents of destruction. Air which contains nitric acid, carbon dioxide, oxygen and watery vapor is an active agent of rock decay. Fresh faces of rocks soon lose their brightness and freshness under the corroding effect of the atmosphere.

Sudden changes of temperature set up strains in rocks which they are not able to withstand and consequently they are broken up, and their fragments exposed to other weathering agents. The wind catching up particles of rocky material blows them with violent force against the surfaces of rocks and wears them away.

Water running over the surface of rocks wears them by means of the rock particles which it carries with it. Falling water beats upon and erodes the surface of soft rock. Waves erode the rocks on the shores, breaking them apart and using the fragments as tools for further destruction. Water also exerts a chemical action on rocks. Some rocks may be dissolved by pure water but others are soluble only in waters containing acids.

Limestones which yield readily to the action of acid-bearing waters are dissolved and carried away in large quantities by surface and underground waters which contain acids derived from decomposing mineral and organic matter. Caverns, sink-holes, and underground streams and passages which represent the dissolved and eroded portions of limestone beds are generally characteristic of limestone regions. Carbon dioxide formed by plant decay and collected from the atmosphere by falling water is one of the most important solvents.

In the presence of moisture oxygen becomes an effective agent of rock decay. Compounds of iron in the rocks are attacked by oxygen and decomposed, thus contributing to the decay of the rock.

The process of oxidation may be accompanied by the process of hydration, in which case the oxidized mineral takes up water. Hydration usually produces a softer mineral, one more easily eroded and thus weakens the rock.

Roots of trees growing in crevices exert a mechanical action which splits the rocks apart, and a chemical action which dissolves them by virtue of vegetable acid from the roots. Man by digging wells, excavating tunnels and cultivating the soil also breaks up the rocks.

The decomposition and the alteration of rocks containing silicates of aluminum is the source of clay. The group of silicates known as feldspars constitutes the most fruitful source of clay. Feldspar is one of the principal constituents of granite and other igneous or metamorphic rocks of the granitoid group. For this reason the formation of residual deposits of clay is closely associated with the disintegration of granite and the subsequent alteration of its silicate minerals.

The disintegration and decomposition of granite is accomplished by the various mechanical and chemical agents which are actively engaged in rock weathering. The alteration of the silicates is accomplished by the action of mineral and vegetable acids carried through the pores of the rock by circulating waters.

One of the most destructive of these acids is carbonic acid (H_2CO_3). This acid first attacks the potash and soda, hence silicates containing these bases are the first to be broken up. Lime and magnesia compounds are next attacked, then the silicates containing iron, and lastly the aluminum silicates, the most stable of the compounds. These complex compounds having been broken up into their component elements, reactions between the elements occur and new compounds are formed. Aluminum uniting with silicic acid forms new silicates which are free from the other bases, and, since they are more readily soluble, are carried away by circulating waters.

The aluminum silicates thus formed are kaolinite, cimolite, halloysite, collyrite, schrötterite, etc.; also some oxides or hydroxides of alumina, such as gibbsite. These aluminous minerals form beds of rock called kaolin. Kaolin is the basis of all clays. The purity of a clay depends upon the percentage of kaolin which it contains. The higher the percentage of kaolin the purer the clay.

The other minerals which are usually associated with kaolin in clays are quartz, calcite, hematite, siderite, limonite, pyrite, feldspar, mica, rutile, lignite and dolomite. The kind and the quantity of these mineral impurities affect greatly the usefulness of the clay. The impurities may have originated from the decomposition of the rock which formed the clay, or they may have been deposited with the clay during a process of transportation and deposition, or they may have been deposited in the clay by circulating waters. The quantity of kaolin present and the amount and nature of the impurities serve as a guide to the uses for which clay may be employed, but the physical properties of the clay must also be considered.

Origin of Clay.

The origin of kaolin has been suggested in the foregoing pages. We have now to consider the origin of the various deposits of clay which are found in the rocks of the lithosphere. The following outline suggests a method of classification of clay deposits according to their origin:

I. Residual clay.
  A. Clays derived from igneous rocks.
    a. Kaolin derived from granite and other feldspathic rocks.
    b. Ferruginous and impure kaolin derived ordinarily from igneous rocks containing hornblende and other ferromagnesian minerals.
  B. Clays derived from metamorphic rock.
    a. Kaolin derived from gneiss and from other feldspathic metamorphic rocks.
    b. Impure kaolin or clay derived from slate, schist or argillaceous marbles.
  C. Clays derived from sedimentary rocks.
    a. Surface clay derived from shale.
    b. Surface clay derived from argillaceous limestone.
    c. Surface clay derived from argillaceous sandstone.

II. Transported clays.

- A. Fluvatile clays, those transported by streams.
  - *a.* Delta clays, those deposited in deltas.
  - *b.* Estuary clays, those deposited in the broad mouths of rivers.
  - *c.* Flood-plain clays, those deposited on the flood plain of rivers.
- B. Lacustrine clays, transported and deposited in lakes.
- C. Marine clays, transported and deposited in marine waters.
  - *a.* Unconsolidated beds of clay.
  - *b.* Shales, compact laminated clays.
- D. Glacial clays, those transported by ice.
  - *a.* Till.
  - *b.* Loess (in part).
- E. Eolian clays, transported by winds.
  - *a.* Loess (in part).
  - *b.* Adobe clays.

Residual Clay.—Residual clays are beds of kaolin or the more common varieties of clay formed in place by the decomposition of other rocks. As has already been stated the disintegration of the rocks is brought about by weathering. The alteration of the constituent minerals is accomplished by acids carried by meteoric waters. The depth to which kaolinization may take place is necessarily limited to a thin outer zone of lithosphere. Very rarely such deposits are of greater thickness than 100 feet, and the greater majority would fall within the limit of a fourth of that thickness.

In exceptional cases kaolinization is thought to be produced by ascending solutions. Under such conditions the deposits may extend to depths greater than those produced by the action of surficial agents. The following table, compiled from Merrill's Rocks, Rock Weathering and Soils, pp. 215–17, illustrates the loss of constituent minerals which crystalline rocks may suffer during decomposition:

TABLE 2.

LOSS OF CONSTITUENT MINERALS IN THE DECOMPOSITION OF CRYSTALLINE ROCKS.

Constituent	Gneiss Fresh	Gneiss Decomposed	Phonolite Fresh	Phonolite Decomposed	Syenite Fresh	Syenite Decomposed	Syenite Decomposed
Silica (SiO_2)..........	60.69	45.31	55.67	55.72	59.70	58.50	46.27
Alumina (Al_2O_3)......	16.89	26.55	20.64	22.19	18.85	25.71	38.57
Iron oxide (Fe_2O_3)....	9.06	12.18	3.14	3.44	4.85	3.74	1.36
Lime (CaO)..........	4.44	Trace	1.40	1.28	1.34	.44	.34
Magnesia (MgO)......	1.06	.89	.42	.44	.68	Trace	.25
Potash (K_2O).........	4.25	2.40	5.56	6.26	5.97	1.96	.23
Soda (Na_2O).........	2.82	1.10	7.12	2.65	6.29	1.37	.37
Phosphoric acid (P_2O_5)	.25	.47	.....	.....	.....	.....	.....
Ignition.............	.62	13.75	4.33	7.79	1.88	5.85	13.61
Total............	100.08%	99.98%	98.28%	99.77%	99.56%	97.57%	101.00%

The first analysis under decomposed syenite represents the first stage in decomposition, while the second analysis represents the last stage in which a kaolin-like residue is produced. The increase in the amount of alumina in all the decomposition products is very noticeable.

Residual clays also result from the decomposition of some limestones and sandstones. Limestones containing just a small per cent of clay will often form clay beds of appreciable thickness through long continued decomposition. Calcium carbonate is dissolved out by meteoric water containing acids and the insoluble clay accumulates. The cementing material of sandstones is dissolved and sand particles and clay particles thus freed are separated by the sorting action of running water. The following analyses of limestone and the residual product exhibit the loss of constituent minerals by decomposition:

TABLE 3.

LOSS OF CONSTITUENT MINERALS IN THE DECOMPOSITION OF LIMESTONE.

Constituent	Limestone 1 Fresh	Limestone 1 Decomposed	Limestone 2 Fresh	Limestone 2 Decomposed	Limestone 3 Fresh	Limestone 3 Decomposed
Silicon dioxide (SiO_2)........	32.81	63.63	20.60	65.30	17.03	76.60
Aluminum oxide (Al_2O_3).....	11.15	10.34	7.63	12.63	21.00	18.37
Iron oxide (Fe_2O_3)..........	4.65	8.75	4.62	12.18	3.33	2.00
Calcium oxide (CaO)........	22.69	3.75	41.81	1.50	29.29	.90
Magnesium oxide (MgO).....	1.53	.50	.81	.63	.....	.....
Sulphur trioxide (SO_3).......	1.55	.34	.25	.25	.72	.70
Moisture (H_2O).............	2.75	4.25	.85	4.75	.75	.55
Volatile matter (CO_2etc.).....	22.61	7.77	23.15	2.27	28.20	.97
Total..................	99.74%	99.33%	99.72%	99.51%	100.32%	100.09%

These samples were taken from the Selma chalk and the residual clay overlying it.

Transported Clay.—The residue formed by the decomposition of rocks may not be allowed to remain on the surface where it was formed. By the action of gravity, of water, of wind, or of ice it may be transported and deposited at some distant point. The particles of such residium accumulating upon a slope will, influenced by gravity, gradually creep to the bottom of the slope. The water which falls upon the slope and runs away to the lower levels to form the rills, brooks and larger streams becomes filled with the finer particles, the size of the particles carried being dependent on the velocity of the water, which in turn is dependent upon the slope. A stream having a velocity of only one-third of a mile an hour is sufficient for the transportation of clay particles. Because of the minute size of the particles and their light weight, clay is one of the first materials to be taken away from a residual deposit by running water. Whenever the stream carrying the particles retards its velocity, it drops its load in proportion to the loss of velocity. A small decrease in velocity will cause the loss of only the coarser particles. A sudden and complete loss of velocity would mean the deposition of all sizes of the materials held in suspension. The presence of coarse sand in clays may thus be explained. Rivers may carry fine particles of rock material to lake or sea and as the waters of the stream mingle with the waters of the larger body they lose their velocity and deposit their load. Thus it is that estuary and delta deposits are formed. Carried by ocean currents and redeposited on the sub-aqueous coastal shelf, beds of marine sands and clays are formed, the coarser material being deposited nearest the shore. Deposits of sand, silt and clay are made on the flood-plains of rivers during the overflow periods. The coarser material is thrown down near the banks of the stream, where the water on leaving the channel loses the greater part of its velocity and therefore its capacity for carrying suspended matter. The finer material is carried farther from the channel and, by the sorting action of water, beds of almost pure clay, the finest material, may be found upon the flood-plain.

Lacustrine clays are clay deposits formed along the shores and on the bottom of lakes, the material of which is derived from the land and carried in by streams. In a similar way marine clays are formed on the ocean bed. When these clay beds, in the course of deposition,

become deeply buried under other deposits they become compacted into a firm clay rock called shale.

During the glacial period vast quantities of rock material were transported by ice and deposited in an irregular sheet of mantle rock to which the name "drift" has been applied. The drift contains in many places beds of clay called till. Streams of water coming from the front of the melting glaciers carried away the fine particles of clay and rock flour and spread them in some places over large areas. This fine, silty material is called loess. Part of the loess was transported and redeposited by winds, thus producing our second form of loess deposits under the head of eolian deposits. Adobe clays of the plains are thought to be of eolian origin.

Classification of Clays.

Clays may be classified according to their origin, according to their mode of occurrence; according to their chemical or physical properties, and according to their uses. A large number of classifications have been suggested by different writers on ceramics. None of these classifications are wholly free from objections for the reason that it is difficult to arrange a grouping which will be free from overlaps. The following classification was arranged by Wheeler:*

1. White ware	Kaolin. China clay. Ball clay.
2. Refractory	Plastic fire clay Flint clay. Refractory shale.
3. Potter's	Plastic clay and shale of moderate fusibility.
4. Vitrifying	Paving brick clay and shale. Sewer pipe clay and shale. Roofing tile clay and shale.
5. Brick	Common brick clay and shale. Terra cotta clay and shale. Drain tile clay and shale.
6. Gumbo	Burnt clay ballast.
7. Slip	Clays of very easy fusibility.

*Clays of Missouri, p. 25.

Wheeler's classification is based primarily on the use of clay. As the term implies the first group of clays is employed in the manufacture of white burning ware. The refractory clays are the fire clays used in the manufacture of fire brick, gas retorts, crucibles, saggars, muffles, etc. Pottery clays are employed in the manufacture of stoneware. Vitrifying clays are used in the manufacture of paving brick, sewer pipe, and roofing tile. Brick clays are those employed in the manufacture of brick, terra cotta and drain tile. Gumbo clays are alluvial clays employed in the manufacture of burnt ballast for road metal. Slip clays are clays of low fusibility and are used to glaze clay wares such as stoneware.

In his Economic Geology of the United States Reis gives the following form of classification based partly on mode of origin and partly on physical characters:

I. Residual clays.
  A. White burning (kaolin, formed from feldspathic rocks).
  B. Colored burning (formed from igneous, metamorphic, and many sedimentary rocks).
2. Clastic, or mechanically formed clays.
  A. Water formed (of variable extent, depending on locality and mode of deposit).
    a. White burning (ball and paper clays).
    b. Colored burning (brick and pottery clays).
  B. Glacial clays (often stony, all colored burning).
  C. Wind-formed clays (some loess).
3. Chemical precipitates (some flint clays).

The following classification of Buckley (Clays and Clay Industries of Wisconsin) is based on the origin of the deposits:

I. Residual, derived from:
  A. Granitic or gneissoid rocks.
  B. Basic igneous rocks.
  C. Limestone or dolomite.
  D. Slate or shale.
  E. Sandstone.

II. Transported by:
  A. Gravity assisted by water. Deposits near the heads and along the slopes of ravines.

B. Ice. Deposits resulting mainly from the melting of ice of the glacial epoch.

C. Water. 1. Marine. 2. Lacustrine. 3. Stream.

D. Wind. Loess.

The classification offered by Ladd (Clays of Georgia) is based on the origin and occurrence of clays. It is given below:

Indigenous.

- A. Kaolins.
  - *a*. Superficial sheets.
  - *b*. Pockets.
  - *c*. Veins.

Foreign or transported.

- A. Sedimentary.
  - *a*. Marine.
    1. Pelagic.
    2. Littoral.
  - *b*. Lacustrine.
  - *c*. Stream.
- B. Meta-sedimentary.
- C. Residual.
- D. Unassorted.

The indigenous clays are those formed in situ and rest upon the rock from which they were derived. The foreign group includes those which have been transported and redeposited. The marine clays were deposited in sea water, the littoral near the shore, and the pelagic in deep water. The lacustrine clays were deposited in lake basins. Stream clays are deposited on the flood plains and in the deltas of rivers. Meta-sedimentary clays are residual clays derived from once transported sediments such as the lighter pyroclastic rocks. Residual clays are those formed by the decomposition of argillaceous sedimentary rocks, such as limestones and sandstones. Unassorted clays include impure glacial clays which contain sand, gravel and bowlders and are often called bowlder clays.

Beyer and Williams use the following classification of which they say: "In the following scheme, which in the main, is the classification offered by Prof. Edward Orton of Columbus, Ohio, the subdivisions

are somewhat more extensive, and while ultimate basis is that of origin, the physical and chemical properties are taken into account in making some of the lesser subdivisions."

- Primary or residual clays
  - Entirely decomposed feldspathic rock...Kaolin or China clay.
  - Partially decomposed feldspathic rock
    - English Cornwall-stone.
    - Porzellan Erde of the Germans.
- Secondary or transported clays
  - Deposited in still water
    - Fire clay
      - Highly refractory
        - Flint fire clay.
        - Plastic fire clay.
      - Moderately refractory
        - No. 2 fire clay.
        - Stoneware clay.
        - Sewer-pipe clay.
    - Indurated shales not metamorphosed
      - Slaty shales.
      - Bituminous shales.
      - Clay shales.
  - Deposited from running water
    - Alluvium.
    - Sandy clays.
    - Loam.
  - Deposited by glacial action
    - Leached—Whitish or red bowlder clay.
    - Unleached—Blue bowlder clay.
  - Deposited by winds—loess.

Uses of Clay.

The uses of clay are so many and varied that it is difficult to make a short, comprehensive classification based upon that factor. However, the more important uses of clay are given in the following groups:

Brick Clays.—Common brick.—These clays may be classified according to the method of molding as soft mud, stiff mud or dry pressed; according to color, as red, salmon, mottled, etc.; according to the position in the kiln, as eye, body; according to position in the building, as front and back; according to form, as hollow, ornamental; according to treatment in burning, as vitrified, lithified, glazed, enameled and adobe (sun dried).

Vitrified brick.—Vitrified brick are made of clay shales and used for pavements and buildings. They are compact, non-porous, stony, have great crushing strength and a high degree of hardness.

Fire brick.—Fire brick are made from highly refractory clays and used in the manufacture of ovens, furnaces, as linings for fireplaces, fire boxes and stoves.

Tile clay.—Tile clay may be either common clay, shale, or fire clay used in the manufacture of drain tile, irrigating tile, roofing tile, floor tile, wall tile and fireplace tile.

Flue clay.—Flue clay is used in the manufacture of chimney flues, ventilating flues and flue brick and tile.

Stoneware clay.—Stoneware clay is used in the manufacture of jugs, churns, crocks, pitchers, jars, urns, jardiniers and sewer pipe.

Earthenware clay.—Earthenware clay is employed in the manufacture of unglazed ware, such as flower pots, filters and drain tile.

China clay.—China clay is used in the production of chinaware, porcelain, graniteware and whiteware, such as urinals, water closet bowls, basins, lavatories and sinks.

Cement clay.—Cement clay is used in the manufacture of Portland cement. When employed for this purpose the clay is mixed with a certain portion of limestone. After being pulverized it is burned to vitrification and reground to a fine flour.

Ballast clay.—Ballast clay is employed in the manufacture of a road metal for walks, wagon roads, railroads, barn floors and also for the purpose of deadening the sound in floors.

Paper clay.—Paper clay is used as a filler for printing paper, wall paper and various other papers. The clay for this purpose is utilized in the raw state.

Fuller's earth.—Fuller's earth is used to refine crude oil. Most clays used for this purpose require washing. All clay must be thoroughly dried and pulverized.

Adulterant clays.—Adulterant clays are employed in the adulteration of soap, paint and food.

Terra cotta clay.—Terra cotta clay is used in the manufacture of terra cotta brick and lumber, both plain and ornamental.

Miscellaneous clays.—Clays are also used in the manufacture of chemical apparatuses, such as evaporating dishes, pestles, mortars, ovens and crucibles. They are used for puddling in reservoirs, to temper soil, as an absorbent, for medicinal purposes, for artists'

moulding material, in relief modeling in schools, in gas retorts, glass pots, smelters, saggars, electric insulating tubes, blocks, door knobs, fire kindlers, fence posts, tombstones, copings, ink bottles, emery wheels.

Occurrence of Clays.

Clays occur either in soft unconsolidated beds or as shale. Shale differs in structure from other clays. It parts readily into thin plates or irregular blocks. The direction of its cleavage is generally horizontal. In hardness it varies from that of the softest clay to that of slate, which is a product of shale metamorphism. In color shales vary, through drab, gray, black and dark blue. Weathered shales are usually yellow, red or brown. By the action of weathering the ferrous iron of the darker shales is changed to the ferric state, thus producing lighter colors. The weathered shales exhibit a higher degree of plasticity than the unweathered. They are also usually very fine grained. In chemical composition they are commonly more uniform than other clays.

CHAPTER II.

CHEMICAL PROPERTIES OF CLAY.

CHEMICAL ELEMENTS OF CLAY.

The chemical elements composing the minerals commonly present in clay are: oxygen, silicon, aluminum, iron, calcium, magnesium, sodium, potassium, titanium, hydrogen, carbon and sulphur. The last two may occur as simple elementary substances uncombined. The other elements are combined to form such compounds as lime, water and silica. In the chemical determination of these elements they are represented as combined with oxygen to form oxides.

TABLE 4.

CHEMICAL COMPONENTS OF CLAY.

Name of Component	*Chemical Symbol*
Silica	SiO_2
Alumina	Al_2O_3
Ferric oxide	Fe_2O_3
Lime	CaO
Magnesia	MgO
Potash	K_2O
Soda	Na_2O
Titanic acid	TiO_2
Sulphur trioxide	SO_3
Carbon dioxide	CO_2
Water	H_2O

Iron, lime, magnesia, potash and soda are classed as fluxing impurities. In clay the lime is usually combined with carbon dioxide (CO_2) to form calcium carbonate ($CaCO_3$), or with water and sulphur trioxide to form hydrous sulphate of lime or gypsum. Other combinations also exist so that an ultimate chemical analysis such as the above does not present, for instance, the amount of gypsum which is present in the clay, but merely the amount of water, lime and sulphur trioxide that is present in the clay. The determination of the percentage of the different mineral compounds in the clay is called its rational analysis. The rational analysis may be computed from the ultimate analysis and is useful in making clay mixtures.

The following table presents the ultimate analysis of clays belonging to each of the three classes of clays found in the State. They were selected to show the variation in the constituent elements in each group, and between each group.

TABLE 5.

ANALYSES OF SOME MISSISSIPPI CLAYS.

KAOLIN.

Constituent	Per Cent No. 1	No. 2	No. 3	No. 4
Moisture (H_2O)	.48	1.11	.20	1.19
Volatile matter (CO_2)	15.01	13.88	7.10	8.00
Silicon dioxide (SiO_2)	44.23	42.92	60.89	39.35
Aluminum oxide (Al_2O_3)	38.82	41.30	29.75	38.73
Iron oxide (Fe_2O_3)	.81	.61	.31	9.39
Calcium oxide (CaO)	.19	.37	.94	.34
Magnesium oxide (MgO)	.13	.13	.35	.70*
Sulphur trioxide (SO_3)	.45	.18	.39	.51
Total	100.12	100.57	99.93	98.21

STONEWARE CLAYS.

Constituent	Per Cent No. 1	No. 2	No. 3	No. 4
Moisture (H_2O)	.54	.77	.94	1.51
Volatile matter (CO_2)	7.40	6.77	6.64	8.07
Silicon dioxide (SiO_2)	59.12	62.58	67.70	61.69
Aluminum oxide (Al_2O_3)	27.44	27.58	19.69	24.91
Iron oxide (Fe_2O_3)	4.39	1.57	3.04	2.04
Calcium oxide (CaO)	.34	.40	1.06	.34
Magnesium oxide (MgO)	.28	Trace	.58	.83
Sulphur trioxide (SO_3)	Trace	Trace	.19	.20
Total	99.51	99.67	100.84	99.59

BRICK CLAYS.

Constituent	Per Cent No. 1	No. 2	No. 3	No. 4
Moisture (H_2O)	5.50	4.25	1.08	1.80
Volatile matter (CO_2etc.)	5.00	7.77	2.11	4.37
Silicon dioxide (SiO_2)	67.60	63.63	80.76	75.21
Aluminum oxide (Al_2O_3)	12.55	10.34	8.50	5.47
Iron oxide (Fe_2O_3)	7.60	8.75	4.50	5.47
Calcium oxide (CaO)	.80	3.75	1.50	.87
Sulphur trioxide (SO_3)	.17	.34	.04	.52
Total	100.00	99.33	98.94	98.88

Reis has summarized the facts to be obtained from the ultimate analysis of a clay as follows (see N. J. Geol. Survey, Vol. VI):

*Includes potassa and soda.

"1. The purity of the clay, showing the proportion of silica, alumina, combined water and fluxing impurities. High grade clays show a percentage of silica, alumina and water, approaching quite closely to those of kaolinite.

"2. The refractoriness of the clay, for, other things being equal, the greater the total sum of fluxing impurities, the more fusible the clay.

"3. The color to which the clay burns. This may be judged approximately, for clays with several per cent or more of ferric oxide will burn red, provided the iron is evenly and finely distributed in the clay, and there is no excess of lime. The above conditions will be affected by a reducing atmosphere in burning, or the presence of sulphur in the fire gases.

"4. The quantity of water. Clays with a large amount of chemically combined water sometimes exhibit a tendency to crack in burning, and may also show high shrinkage. If kaolinite is the only mineral present containing chemically combined water, the percentage of the latter will be approximately one-third that of the percentage of alumina, but if the clay contains much limonite or hydrous silica, the percentage of chemically combined water may be much higher.

"5. Excess of silica. A large excess of silica indicates a sandy clay. If present in the analysis of a fire clay it indicates low refractoriness.

"6. The quantity of organic matter. If this is determined separately, and it is present to the extent of several per cent, it would require slow burning if the clay was dense.

"7. The presence of several per cent of both lime (CaO) and carbon dioxide (CO_2) in the clay indicates that it is quite calcareous."

In order to determine the amount of clay substance in any of the analyses given in table 5, we may consider all the clay minerals to have the same chemical composition as kaolinite (Al_2O_3, $2SiO_2 + 2H_2O$). The average composition of some beds of kaolin is very close to the theoretical composition of kaolinite. The latter contains 39.5 per cent of alumina, 46.5 per cent of silica and 14 per cent of water. However, some beds of pure kaolin may exhibit less alumina than is contained in kaolinite. Such would be the case were the predominant mineral cimolite. On the other hand the amount of alumina

present might exceed the amount in kaolinite. In this case the predominant mineral might be collyrite or a mixture of some other of the aluminum silicates with gibbsite. The amount of alumina in the first kaolin in the table above given falls a little below the amount in kaolinite. To obtain the percentage of kaolinite from the ultimate analysis multiply the quantity of alumina (38.82) by the factor 2.53 and the result obtained is 98.21 per cent instead of 100 per cent, as it would have been in the case of pure kaolinite. Now, if the amount of alumina be multiplied by the factor, 1,176, the amount of silica which enters into combination with the alumina to form kaolinite may be obtained. The amount of combined silica is found to be 45.65 per cent. But the total amount of silica is only 44.23, so that there is lacking 1.42 per cent of the silica necessary to combine with the alumina to form kaolinite. Two explanations are relevant. The kaolin may be composed largely of a mineral like collyrite, which is higher in percentage of alumina than kaolinite. Under such conditions there would be some free silica in the kaolin. The same conditions might be brought about as the result of a mixture of these two minerals, collyrite and kaolinite. On the other hand, this composition of the kaolin may be explained by assuming the presence of aluminum oxide (gibbsite) with the aluminum silicate or silicates.

Kaolin No. 2 of table 5 contains 1.8 per cent more alumina than is required for kaolinite. It also contains 7.64 per cent less silica than the amount required to satisfy the alumina. Computed as kaolinite it contains 104.48 per cent. This condition very strongly suggests the presence of gibbsite.

The amount of kaolin in the first stoneware clay of table 5 is 69.42 per cent and the amount of silica is 26.86 per cent. The decrease in the amount of clay substance in the brick clays is still more marked. The first in the table contains the highest per cent, 31.75. More than half of this clay consists of uncombined silica.

CHEMICAL COMPOUNDS OF ULTIMATE ANALYSIS.

Before taking up a discussion of the minerals commonly occurring in clays a short discussion of the chemical compounds revealed by the ultimate analysis will be given.

SILICA.

The silica, the percentages of which are expressed in the analyses of table 5, may be divided, in respect to its influence on the clay, into three parts. The first portion is that which is combined with the alumina to form the kaolin group of minerals. The second portion is combined with other silicates, such as feldspar, hornblende and mica. The third portion is uncombined silica known as free silica or sand. In making a rational analysis of a clay the last two are rarely separated. The usual method is to compute the amount of silica combined to form kaolinite. This amount called combined silica is deducted from the total amount of silica as revealed by the ultimate analysis and the remainder is called free silica. Reis has pointed out that this method is not entirely satisfactory from the clay workers' standpoint, since some of the silicates have very different properties from the quartz and may exert a very different influence on the clay ware. The effects produced upon clay by the presence of free silica are to influence its texture, its bonding power, its plasticity, its strength, its fusibility and other physical properties. These effects are discussed under physical properties of clay.

ALUMINA.

The alumina revealed by the chemical analysis is derived largely from the kaolin in the clay, but a part may be derived from feldspar and other aluminous minerals. The amount of alumina in the Mississippi clays thus far analyzed ranges from a few per cent to 41 per cent. Alumina is the most refractory substance found in clays. Besides contributing to the refractoriness of the clay it also furnishes the bonding material for holding together the inert particles. Without its presence the material could not be fashioned into the desired form.

Part of the water found in clay is in chemical union with alumina to form some hydrous silicate like kaolinite. Besides the kaolinite there are other minerals which contain water of crystallization, such, for example, as gypsum. The combined water is given up when the clay is subjected to high temperatures. Clay also contains some mechanically combined water which may be driven off at the temperature of boiling water. The amount of mechanically combined water is given in the ultimate analysis under the head of moisture.

IRON OXIDE.

The amount of iron oxide varies in different clays. It is generally least in kaolins and highest in brick clays. The chief source of iron oxide in clay is from compounds of iron, but a small amount may be derived from ferro-magnesian minerals. The iron compounds, such as hematite, limonite and siderite, may exist either in a finely divided state or as concretions in the clay. Limonite on the application of heat loses its water of crystallization and becomes red oxide of iron. It is to this last compound that the red color of clay wares is due. Siderite, the carbonate of iron, under the influence of heat gives up its carbon dioxide and becomes ferrous oxide. In the presence of oxygen the ferrous iron may be changed to the ferric oxide, the red oxide.

The sulphide of iron may also be reduced to the ferric oxide under the action of heat. Iron is also a fluxing ingredient of clays. When the iron compound is reduced to the ferrous state in the absence of oxygen it will unite with silica forming a ferrous silicate. In the presence of other easily reducible compounds the ferrous silicate may act as a rapid solvent. If there is plenty of oxygen present the ferrous oxide will be further oxidized to the more refractory ferric state.

CALCIUM OXIDE (LIME).

The amount of lime in clays is generally below five per cent. Some brick clays, however, contain as much as twenty per cent. The origin of the lime is from limestone (calcium carbonate) and gypsum (calcium sulphate). Small amounts of lime may be derived from lime-bearing silicates, some of which are of common occurrence in clays. The effect produced by the presence of lime in clay will depend on the distribution of the lime and the amount present. Lime concretions may produce cracks in bricks by absorbing water and slaking after the brick are burned. In the presence of iron these concretions may fuse and cause cavities or slaggy masses in the brick. The same amount of lime finely divided and uniformly distributed through the clay would have no detrimental effect. However, since lime acts as a flux, its presence in appreciable quantities tends to lower the fusion point of the clay. For this reason vitrifying clays should not contain much lime. In the presence of a considerable

quantity of iron the fluxing action of lime may be rapid and effective. With only a small increase of temperature above incipient fusion the brick may be reduced to a slaggy mass. Lime in considerable quantities in a common brick clay may also prevent the development of a red color in the ware.

MAGNESIA.

The source of magnesia in clay is from magnesium carbonate, from magnesium sulphate, and more rarely from silicates containing magnesium. Dolomite or magnesium limestone is the chief source. This mineral is a calcium-magnesium carbonate ($\frac{1}{2}$ Ca, $\frac{1}{2}$ Mg, CO_3). By the decomposition of pyrite in clays sulphuric acid may be formed. The latter may attack the magnesium carbonate and form magnesium sulphate. The sulphate is soluble in water and if the drainage of the clay bed is perfect it will cause the sulphate to be carried out by circulating waters. If the sulphate is not separated from the clay it will be brought to the surface of the ware either in drying or burning and produce efflorescence. The action of magnesia under heat is said to correspond to that of lime with the exception that at high temperatures the magnesia is not as rapid a fluxing agent as lime.

ALKALIES.

The alkalies commonly found in clays are potash (K_2O) and soda (Na_2O). The per cent of alkalies contained in the clays of Mississippi so far determined is small. Alkalies in clays are commonly derived from silicate mineral, such as feldspar. The compounds of potassium and sodium formed by the breaking down of these complex compounds are sulphates, carbonates and chlorides. These compounds being soluble are removed from the clay under perfect drainage conditions. Imperfectly drained clay beds may contain a considerable amount of these compounds. The alkalies act as powerful fluxes. They fuse at a low temperature, the soluble salts at about red heat. The silicates fuse at higher temperatures. The soda silicates fuse at lower temperatures than the potash silicates The feldspars are considered an aid to vitrification since they produce a longer period between incipient fusion and complete vitrification They are detrimental to high degree of refractoriness

MINERALS IN CLAYS.

The minerals composing clays may be classed as essential and non-essential. The determination of essential components will be controlled by the use for which the clay is intended. Iron, for example, is an essential element in any clay intended to be red-burning. On the other hand it is non-essential and detrimental to a clay intended to be white-burning.

The minerals most commonly found in clays are silica, feldspar, mica, iron compounds, such as hematite, limonite, magnetite, siderite and pyrite, kaolinite, calcite, gypsum and hornblende. Others occurring somewhat less commonly are rutile, glauconite, dolomite, garnet and fluorite. Pure clay is a mixture of kaolinite, meershaluminite, halloysite, newtonite, cimolite, pyrophyllite, allophane, collyrite, montmorillonite and schrötterite, silicates of aluminium and gibbsite, an oxide of aluminium. Rock formed of one or more of these minerals is called kaolin. All the other minerals found in clay are termed impurities. The clay compounds and the impurities result from the decay of rocks. For example, granite composed, say, of feldspar, mica and quartz, may, by decomposition, form allophane, cimolite, kaolinite, biotite, quartz, magnetite, damourite, epidote, gibbsite, muscovite, chlorite, diaspore, limonite, pyrophyllite, newtonite, hematite and hypersthene. Further alteration may result in the formation of other compounds. In the following pages a discussion of the properties of some of the minerals commonly found in clays are given.

KAOLINITE.

Kaolinite (Al_2O_3, $2SiO_2$, $2H_2O$) is an hydrous silicate of aluminum containing 46.5 parts of silicate; 39.5 parts of alumina and 14 parts of water. It is a compact friable or mealy mineral having a greasy feel. It is composed of microscopic scales or crystals which in the aggregate are white in color. It is a soft mineral having a specific gravity of 2.63. Kaolinite results from the decomposition of aluminous minerals, especially the feldspars, one of the common and essential constituents of granites and gneisses. It is found in the rocks of all ages from the Archean to the Recent. Some of the varieties of kaolinite contain more alumina and less water than that in the for-

mula given above. Beds of kaolinite and associate minerals are called kaolin.

In the decomposition of feldspar to form kaolin, the potash and other bases are removed by the action of meteoric waters containing carbon dioxide. The residual aluminium silicate takes up water, forming an hydrous aluminium silicate or oxide. The aluminous minerals found in kaolin are here given:

TABLE 6.

ALUMINOUS MINERALS FOUND IN KAOLIN.

	Silica	*Alumina*	*Water*
Kaolinite, $H_4Al_2(Si_2O_9)$	46.05	39.5	14.0
Meerschaluminite, 2HAl (SiO_4) + aq	43.15	41.07	15.78
Halloysite, $H_4Al_2(Si_2O_9)$ + aq	43.5	36.9	19.6
Newtonite, $H_8Al_2(Si_2O_{11})$ + aq	38.5	32.7	28.8
Cimolite, $H_6Al_4(SiO_3)_9$ + aq	63.4	23.9	12.7
Pyrophyllite, $H_2Al_2(SiO_3)_4$	66.7	28.3	5.0
Allophane, $Al_2(SiO_8)5H_2O$	23.8	40.5	35.7
Collyrite, $Al_4(SiO_8)9H_2O$	14.1	47.8	38.0
Schrötterite, $Al_4(SiO_8)30H_2O$	11.7	53.1	35.2
Gibbsite, $Al_2O_33H_2O$	......	65.4	34.6

SILICA.

Silica (SiO_2) is usually the most abundant mineral in clays. The composition of silica is silicon, 46.7 parts and oxygen, 53.3 parts. It exists in clay either free or combined. Combined with other substances it forms silicates. The amount of free silica or quartz sand occurring in clay varies from 1 to 50 per cent. The total amount of silica may be much higher, often as much as 70 or 80 per cent. In such clays the percentage of free silica is very high.

The size of the quartz grains in clays is extremely variable. They range from those particles large enough to be removed by screening to those of exceedingly small microscopic size. The grains are transparent, of milky translucence or stained by iron compounds. Quartz grains which have not been transported are usually angular in form. The transported grains have become rounded by the abrasion incurred during transportation. Since quartz is a very hard mineral, being seventh in the scale of hardness, it is not easily broken up, and because of its insolubility it is not easily decomposed. For these reasons it forms a considerable portion of many sedimentary rocks, and especially of the mantle rock.

Quartz alone is nearly infusible, being fused at cone 35 of the Seger series, a temperature of about 3,326° F. Although of such high refractoriness it may or may not add to the refractoriness of a clay. Under certain conditions, as when the amount of fluxing materials is high, an addition of quartz may raise the fusion point, but such fusion point will be much lower than the fusion point of pure quartz. Quartz added to clay having a low per cent of fluxing impurities may tend to lower the fusion point of the clay.

The addition of quartz to clay will reduce the shrinkage of the clay. It will also decrease the plasticity but the amount of reduction will depend on the size of the quartz grains. Clays containing a high percentage of quartz of coarse grain slake more readily than other clays. Clays containing a high percentage of very finely divided quartz slake slowly and are very sticky clays. Quartz of coarse grain adds to the porosity and absorption power of a clay.

IRON.

The element iron may occur in clays in a number of forms. It may be present as a sulphide, an oxide, a carbonate, an hydroxide, a sulphate or a silicate. In the manufacture of some clay wares a limited amount of iron is desirable. For instance in red ware such as brick and tiling the color is dependent on the oxidation of the iron compounds in the clay. A very low per cent of iron is desirable in a clay to be used in the manufacture of white ware of any kind. Some clays burn white notwithstanding the presence of a large per cent of iron; especially is this true when a considerable portion of carbonate of lime is present. The iron compounds commonly found in clays are limonite, hematite, siderite and pyrite.

Limonite.—Limonite is an hydroxide of iron ($2Fe_2O_3$, $3H_2O$). It contains 59.8 per cent of iron, 25.7 per cent of oxygen, and 14.5 per cent of water. As an ore it may occur in rather compact crystalline masses or as grains mixed with clay, in which form it is called yellow ochre. The yellow or brown color of many clays is caused by the presence of appreciable amounts of limonite. Limonite may occur in clays as a coating for the sand grains, as distributed through the clay in very fine particles, and as large lenticular concretions. It occurs as bog ore in ponds and marshes, having been brought into the water in a soluble form as a sulphate or carbonate or as some

organic salt through the action of some organic acid. It is precipitated by oxidation and its presence is revealed by an iridescent oil-like film upon the surface of the water. Limonite may result from the alteration of other ores, through the action of atmospheric agents and the presence of organic acids. Through alteration processes it is derived largely from pyrite, magnetite, siderite and from silicates containing iron in the ferrous state. Under the action of carbon dioxide it may be changed to siderite. By hydration it may be changed to hematite. It forms the cementing substance for many sandstones and conglomerates. Under the influence of heat limonite loses its water of crystallization and is changed to the red oxide.

Hematite.—The red oxide of iron (Fe_2O_3) is also a common constituent of clays. This compound contains 70 per cent of iron, and 35 per cent of oxygen. It is found widely distributed through the rocks of the earth's crust. It occurs in the form of tabular or rhombohedral crystals known as specular iron. In hexagonal plates it is known as micaceous hematite. In minute particles it is found as a coating for sand grains and is also disseminated through clays and other rocks of this form. It sometimes occurs in clays in concretionary masses. These masses may be coated with limonite which is the beginning of the process of alteration. In beds of soft rock it forms red ochre. The occurrence of hematite may be due to the alteration of some other iron compound. For instance pyrite by oxidation may be changed to hematite. Magnetite and siderite may also be altered to hematite. Silicates such as hornblende, for example, may be decomposed, producing hematite as one product. Hematite may be altered to magnetite and then changed to siderite by the action of carbon dioxide. When acted on by sulphuretted hydrogen it may form pyrite, or by taking up water it may become limonite.

Siderite.—The carbonate of iron ($FeCO_3$) may occur in clays as minute particles somewhat uniformly distributed and as concretionary masses. Siderite contains 62.1 per cent of iron protoxide and 37.9 per cent of carbon dioxide. It is found in many sedimentary and metamorphic rocks. In shales and clays it frequently occurs as iron stones, especially in beds associated with coal deposits. There are several varieties based on composition. Some of these contain magnesium, others manganese, and still others calcium. There are

also several varieties as to form. It may be crystalline, earthy, concretionary, granular, compact or oölitic.

Where uniformly distributed through clay it may give it a slate color. By oxidation siderite may be altered to hematite, to limonite or to magnetite. When present in considerable quantities in a clay it may act as a flux, causing the clay to be fused at a lower temperature. When heated it loses its carbon dioxide and becomes ferrous iron (FeO). The FeO may unite with silica and form a ferrous silicate, FeO_2, $2SiO_2$, which gives to the ware a dark green color.

Pyrite.—Iron pyrites or fool's gold is a bright brassy mineral of common occurrence in clays and shales. Its chemical symbol is FeS_2, and its composition is iron 46.6 per cent and sulphur 53.4 per cent. Its common occurrence in clay is in the form of crystals or concretionary nodules of various shapes. Many of these are radiate in structure. In the presence of air and moisture the pyrite (FeS_2) alters to iron sulphate, iron oxide and sulphur. If lime carbonate is present the iron may be changed to the hydroxide and the sulphur trioxide uniting with the calcium may form gypsum ($CaSO_4$, $7H_2O$). Thus by the action of weathering pyrite may be removed from clay. Pyrite may be changed to limonite by oxidation and hydration. By dehydration the limonite may be altered to hematite.

When FeS_2 is subjected to heat the Fe becomes oxidized to FeO and the sulphur is converted into SO_2 or SO_3. At low temperatures FeS_2 loses S and becomes FeS. At still higher temperatures FeS is changed to FeO and SO_2. In the presence of oxygen the SO_2 may be converted into SO_3.

Marcasite.—Marcasite is a variety of iron disulphide having the same chemical composition as pyrite. It is a common impurity in lignitic clays. Its color is pale bronze-yellow. In clays it frequently occurs in nodules of radiating crystals called "sulphur balls." Atmospheric alteration of marcasite takes place very rapidly. For this reason weathering the clay is one of the most effective means of removing the impurity.

Ilmenite.—The mineral ilmenite, or menaccanite, is an oxide of iron and titanium ($TiFeO_3$ or $(TiFe)_2O_3$). It is an opaque mineral of black or brownish-black color. The normal variety contains 31.6 per cent of titanium, 36.8 per cent of iron, and 31.6 per cent of

oxygen. Since this mineral is very refractory and not easily acted on by the agents of decomposition, it is a common constituent of many residual and transported deposits. It also occurs as an original constituent of many igneous rocks. It is sometimes found in tabular crystals, plate like masses or in grains in veins of metamorphic rocks. In many sedimentary rocks it is present in small rounded grains. There are a number of varieties of the mineral distinguished by varying proportions of iron and titanium. In some species the iron is partly replaced by magnesium. Ilmenite may be altered to leucoxene or titanite.

GYPSUM.

Gypsum ($CaSO_4 2H_2O$) is a hydrous sulphate of calcium. It is composed of 32.6 parts of lime, and 20.9 parts of water, and 46.5 parts of sulphur trioxide. Gypsum occurs as individual crystals, as crystalline aggregates, as crystalline sands, or in massive beds of earthy material. It may be precipitated from sea water under conditions similar to the deposition of common salt. It may also result from the decomposition of pyrite in the presence of lime carbonate. The reactions involved are as follows:

$FeS_2 + 6O = FeSO_4 + SO_2$ or

$FeS_2 + 3O + H_2O = FeSO_4 + H_2S$.

Then $FeSO_4 + 2O + 7H_2O = 2Fe_2O_3 \ {:}3H_2O + 4H_2SO_4$.

In the presence of lime

$CaCO_3 + FeSO_4 = CaSO_4 + 2H_2O + FeCO_3$ or

$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$.

There are several varieties of gypsum, the clear, transparent, crystalline kind is called selenite. Satin spar is a fibrous variety with a satin-like lustre. Alabaster is a white, fine-grained variety used in making ornaments. Gypsite is an earthy variety occurring in thick beds of varying purity. Selenite and gypsite both occur in some of the clays of Mississippi. Aggregates of selenite crystals are of common occurrence in the clays of the Jackson group. By the decomposition of pyrite in the presence of lime carbonate. By the decomposition of pyrite in the Selma chalk the residual clays of that formation contain sufficient gypsum in some localities to cause efflorescence on brick manufactured from the clay. A discussion of the effects of gypsum may be found under lime and efflorescen e.

CALCITE.

The mineral calcite ($CaCO_3$) is composed of 56 parts of lime (CaO) and 44 parts of carbon dioxide (CO_2). Calcite is the chief constituent of limestone, chalk and marble. It occurs also in marls, shales and sandstones in small grains or crystals. Its presence in sedimentary rocks is largely due to the accumulation of organic remains, and possibly to a less extent to precipitation from aqueous solutions. There are several varieties of calcite. Iceland spar is a clear transparent variety having the power of double refraction. Dog-tooth spar occurs in crystals, the form of which suggests the name. Aragonite has the same chemical composition as calcite but differs in its crystallization. Marble, or crystalline limestone, is composed largely of calcite. Tufa, travertine and argentite are composed principally of calcium carbonate.

When calcite is heated to a temperature of 1,296° F the CO_2 in composition is driven off and lime (CaO) remains. On the addition of water the calcium oxide (CaO) will be changed to calcium hydroxide ($Ca(OH)_2$) with the evolution of heat.

Nearly all clays contain at least small quantities of calcite. The presence of calcite tends to lower the fusion point of the clay. Where present in large quantities or where unevenly distributed it may produce cracking or breaking of the brick due to the evolution of gas and of heat in slaking. Unless the brick are porous it is possible for the outside of the brick to vitrify before all of the gas has been expelled from the inside. This causes a swelling or puffing of the brick.

Many residual clay deposits have been formed by the decomposition of limestone containing clay. The lime carbonate is dissolved by acidulated meteoric waters and carried away, while the insoluble clay is left as a residual product. The amount of clay in the limestone may be exceedingly small, yet in time and under the proper conditions a bed of clay of considerable thickness may accumulate. Such residual clays have been formed in Mississippi by the dissolution of the Selma chalk and the Vicksburg limestone. Beds of clay so formed usually rest directly upon the surface of the limestone and often contain, especially in the lower portions, nodules of lime carbonate which represent the more insoluble parts of the limestone. These are often a source of annoyance to the brick maker. They interfere with the cutter and cause flaws in burning

If the bottom clay is used it ought to be crushed so as to distribute the lime through the clay, in which condition it is harmless.

FELDSPAR.

The feldspars are silicates of aluminum containing calcium potassium, sodium or barium. There are nine principal varieties which are divided crystallographically into two groups: first, the monoclinic feldspars, orthoclase and hyalophane; second, the triclinic feldspars, microcline, anorthoclase, albite, oligioclase, andesine, labradorite and anorthite. The chemical constituents of each of these feldspars is given in the following table from Dana's Mineralogy:

TABLE 7.

CHEMICAL COMPOSITION OF FELDSPARS (DANA).

Species	*Silica* SiO_2	*Alumina* Al_2O_3	*Potash* K_2O	*Soda* Na_2O	*Lime* CaO	*Barium* Ba
Orthoclase	64.7	18.4	16.9	....	....	....
Hyalophane	52.0	22.0	7.0	3.0	1.0	15.0
Microcline	65.0	18.0	17.0	....	....	....
Anorthoclase	66.0	20.0	4.0	7.0	1.0	....
Albite	68.0	20.0	....	12.0	12.0	....
Oligioclase	62.0	24.0	....	9.0	5.0	....
Andesine	57.0	27.0	....	9.0	7.0	....
Labradorite	53.0	30.0	....	4.0	13.0	....
Anorthite	43.0	37.0	....	....	20.0	....

Feldspar is found in crystals in igneous and metamorphic rocks and as grains in some fragmental rocks. It is one of the essential constituents of granite. By the action of carbonate waters on lime and other bases of feldspar they may be taken into solution and the feldspars decomposed. The decomposition of the feldspar results in the formation of new compounds. These new compounds are aluminous silicates like kaolinite. The decomposition of pyrite may produce sulphuric acid which will aid in the decomposition of feldspar. The decomposition of feldspathic rocks is the original source of clay.

Feldspar is commonly associated with quartz in sand and is for that reason a constituent of most clays. Like quartz it serves to decrease shrinkage in clays, but since it fuses at a much lower temperature (2,192° F) it may form a chemical union with other substances and act as a flux.

MICA.

Mica is a polysilicate composed of iron, aluminum, calcium, magnesium, manganese and silica. The mica group of minerals contains more than a half dozen important varieties. They are all silicates of aluminum but vary in other constituents, viz.: potassium, lithium, magnesium and iron. There are two common varieties. The first is a white variety called muscovite. It has the following composition: silica, 45.2 per cent; alumina, 38.5 per cent; potash, 11.8 per cent, and water, 4.5 per cent. The second is a black or dark variety, called biotite $(Mg, Fe)_2 Al_2Si_3O_{12})$, the potassium of the former being partly replaced by magnesium and iron. One of the most notable physical characters of mica is its perfect cleavage in one direction permitting it to be separated into very thin plates. It has a low degree of hardness.

Mica is an essential constituent of many igneous and metamorphic rocks. When granite and other mica-bearing rocks are decomposed the crystals of mica are broken up into small thin flakes. These flakes are found in residual clays, and on account of the low specific gravity of the particles, are transported long distances and occur in most transported deposits.

Under the action of weathering mica may lose its potash and take up water and soda, manganese or lime. In brick clays the mica grains may be little affected by a temperature sufficiently high to produce a serviceable brick, and the bright unchanged particles are sometimes seen upon the surface of a fresh fracture. At high temperatures the mica may be fused and it is therefore detrimental to fire clays if present in sufficient amount. Because of the presence of iron it is detrimental to white ware burned at high temperatures.

HORNBLENDE.

Hornblende is a silicate belonging to the amphibole group of bisilicates. In contains 48.8 parts of silica; 18.8 parts of iron; 13.6 parts of magnesia; 10.2 parts of lime and 1.1 part of manganese. It may occur in crystals, fibers or in a massive form. It is an essential constituent of diorite, and also occurs in other rocks. There are many varieties of hornblende. Actinolite, asbestus,

nephrite and tremolite are light colored varieties. Pargasite, beramaskite and black hornblende are varieties of the dark colored amphiboles. There is a great variety of colors. The predominant colors are black, white, green and brown. Hornblende is hard and has a vitreous or silky lustre. The residual product of the decomposition of hornblende is a clay which contains a high per cent of iron. The iron compounds which may be formed by its decomposition are limonite, magnetite and hematite.

CHAPTER III.

PHYSICAL PROPERTIES OF CLAY.

The physical properties of clay which, from the clay-workers' standpoint, are most valuable, are plasticity, strength and refractoriness. Plasticity enables the worker to fashion the clay into the desired form. The strength of the clay permits the clay ware to be handled during the drying and burning processes without danger of breakage. The power of the clay to withstand high temperatures permits it to be burned to a compact, hard body of permanent form. While these are, for the majority of wares, the most important physical properties there are other properties of very great importance in the manufacture of some wares. In our investigation of the clays included in this report, we have considered the following properties:

Structure.	Feel.	Fusibility.
Shrinkage.	Odor.	Fineness of grain.
Specific gravity.	Taste.	Bonding power.
Color.	Slaking.	Tensile strength.
Hardness.	Plasticity.	Porosity.

STRUCTURE.

The structure of a clay refers to its mode of occurrence in the outcrop or pit. A stratified clay is one which occurs in layers. A massive clay is one in which no division planes are seen. A clay which splits readily in thin leaves or irregular blocks is said to be shaly. If the leaves are small, thin and light the term chaffy is applied to it. A slaty clay is one in which the laminae have undergone a considerable degree of induration. Instead of occurring in layers some clays are found in concretionary or pebbley masses. Joint clays are those which are separated into blocks by vertical crevices. This structure is an aid to the mining of many clays. These various structures in clay are the result of deposition, compression, and induration. In the process of weathering they are obliterated, and the rapidity of such weathering action is often dependent on the

structure of the clay. The speed with which a mineral producing soluble salts can be removed by weathering will depend upon the structure of the clay. In order that clay may be used in the formation of clay wares, it must be reduced to a structureless mass. For this purpose it is necessary to employ disintegrating or pulverizing machinery. The expense of this process will be determined by the degree of induration which has taken place in the clay structure.

SHRINKAGE.

The amount which a clay contracts in passing from a plastic condition to that of a rigid solid is termed its shrinkage. The water which is added to the clay in order to render it plastic is lost by evaporation, causing a loss of volume. The loss of volume or shrinkage varies greatly in different clays and with different conditions of the same clay. Water added in excess of the amount required for plasticity will cause a greater loss of volume, as will also the presence of air bodies in the clay. Considerable water may exist in the clay without increasing the volume, but whenever the particles of clay are completely enveloped in water, the volume and the plasticity will be increased. Water absorbed by a clay exists either interstitial, *i. e.*, in the pores, or interparticle, *i. e.*, not occupying the pores but causing a separation of the particles. It is the latter which increases the volume of a clay. Clays of coarse grain have large interstices and contain large quantities of interstitial water, but less interparticle water than clays of finer grain; therefore, the fine grain clay shrinks more than the coarse grain.

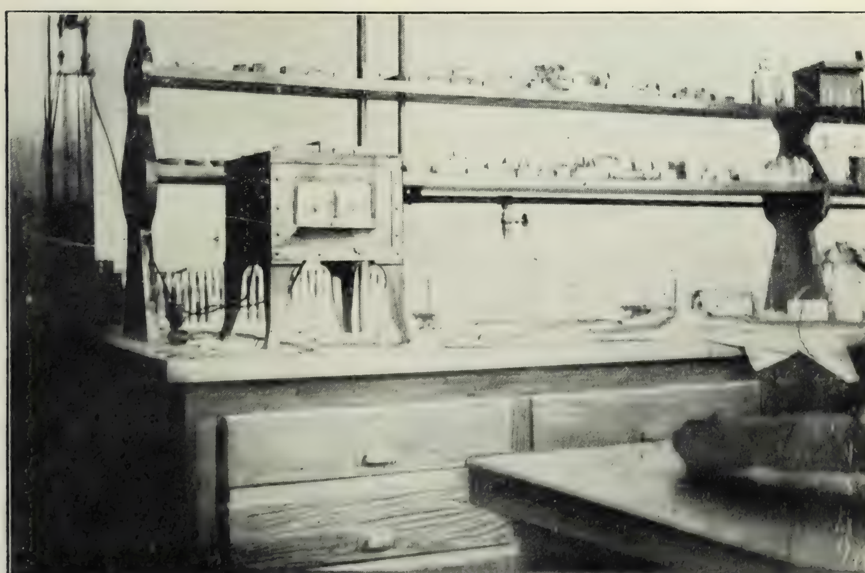
AIR SHRINKAGE.

The amount of contraction which a clay undergoes when drying in the air is called its air shrinkage. The amount of air shrinkage depends mainly on two factors; first, the amount of water absorbed; second, the size of the grain.

A number of methods of preventing excessive shrinkage is employed. The method more generally in use is that of mixing a sandy clay with the more plastic clay. Under ordinary conditions this is the most economical method. In the greater part of the surface clay deposits of this State the upper portion of the clay bed contains available sandy clay. The plastic, residual clays are sometimes diluted with the underlying non-plastic loess. Pure sand and crushed brick are sometimes used to decrease shrinkage and produce

PLATE III.

A. BRICKETTES FOR TENSILE STRENGTH TEST.



B. ELECTRIC FURNACE FOR TESTING CLAYS.

more rapid drying. Crushed coal cinders are successfully employed in some plants. Chopped straw, sawdust, lignite and coal dust may also be employed. The effects produced by the use of non-plastic materials is to decrease its plasticity and its bonding power. On the other hand, they may cause the clay to mold without lamination, increase the speed of drying and burning, and prevent cracking and checking. The use of combustible substances leaves the brick more porous than the mineral substances. From a fuel standpoint their use is economical, since the clay particles are brought in immediate contact with the clay. The danger of swollen ware will be referred to under the subject of "Causes of Swollen Brick." Unless a large amount of oxygen is supplied to the kiln in the draft the organic matter in the clay may rob the iron compounds of their oxygen and cause a pale yellow color in red burning clays. The use of cinders is free from some of these objections. They decrease shrinkage, plasticity, bonding power, and tensile strength in the raw clay. They cause the clay to dry more rapidly and to burn in less time. They do not increase the porosity of the clay as do the combustible substances and the tensile strength of the burned clay is not diminished as much. The table below shows the effect of coal and cinder dilution on the tensile strength of raw and burned clays.

TABLE 8.

EFFECT OF COAL AND CINDER DILUTION ON THE TENSILE STRENGTH OF RAW AND BURNED CLAYS.

	Tensile strength in pounds per square inch.	
Locality	*Raw clay*	*Burned clay*
Starkville brick clay	133	146
Starkville brick clay and 10% coal	119	150
Starkville brick clay and 10% cinders	75	153
Amory brick clay	100	220
Amory brick clay and 10% coal	140	263
Amory brick clay and 10% cinders	175	300
Morton clay	81	131
Morton clay and 10% coal	130	192
Morton clay and 10% cinders	100	235
Wahalak clay	112	170
Wahalak clay and 10% coal	77	222
Wahalak clay and 10% cinders	74	150

The first clay is residual Selma, the second is Tombigbee second bottom, the third is a residual Jackson and the fourth belongs to the Porter's Creek (Flatwoods) formation. These clays are all highly

plastic and the shrinkage is excessive. The non-plastic material was added to decrease shrinkage and to increase the speed of drying and burning. All of these objects were attained, and, as the experiments seem to prove, not greatly at the expense of the strength of the ware when the ware is compared with that of the original clay. The brickettes were given a medium burn.

FIRE SHRINKAGE.

The loss of volume which the clay sustains in passing from the raw to the burned condition is termed its fire shrinkage. The loss of the chemically combined water in clay and the combination of the organic matter causes an increase in the porosity of the clay. When the temperature is carried to the point of vitrification the pore space and the natural pores are closed. A loss of volume results. Sandy clays not burned to vitrification may not exhibit any fire shrinkage. Some clays containing a high per cent of organic matter when subjected to a rapidly increasing temperature may become viscous on the outside, thus preventing the escape of hydrocarbons formed from the distillation of the organic matter and causing the brick to slightly increase in volume.

The following table shows the air shrinkage and the fire shrinkage of some Mississippi brick clays burned at a good red heat and forming a medium burn.

TABLE 9.

SHRINKAGE IN MISSISSIPPI CLAYS.

Formation	*Locality*	*Air Shrinkage*	*Fire Shrinkage*
Brown loam (middle)	Vicksburg	$3\frac{1}{2}$%	0 %
" "	Lexington	$3\frac{1}{3}$%	0 %
" " (bottom)	Sardis	$6\frac{2}{3}$%	2 %
" "	Holly Springs	$3\frac{1}{3}$%	1 %
Yazoo alluvium (buckshot)	Indianola	10 %	2 %
" " "	Moorhead	15 %	3 %
" " "	Greenville	10 %	$2\frac{1}{2}$%
" " (sandy)	Elizabeth	5 %	1 %
" " "	Clarksdale	4 %	$2\frac{2}{3}$%
" " "	Minter City	5 %	1 %
Porter's Creek (Flatwoods)	Macon	10 %	2 %
" " "	Wahalak	10 %	2 %
" " "	Starkville	10 %	1 %
Lafayette	Canton	8 %	0 %
"	Hernando	5 %	1 %
Jackson	Canton	10 %	1 %
"	Morton	10 %	1 %
"	Barnett	10 %	2 %
Buhrstone	Vaiden	10 %	0 %
Selma residual	Starkville	5 %	1 %
" "	West Point	4 %	0 %
" "	Booneville	5 %	1 %
" "	Verona	5 %	1 %

SPECIFIC GRAVITY.

The specific gravity of a rock is its weight compared with the weight of an equal volume of distilled water at 60°F. The specific gravity of a substance is obtained by weighing it in air and by weighing it in water and then dividing its weight in air by its loss of weight in water. The specific gravity of clays usually varies from 1.50 to 2.50, but there are some clays whose specific gravity is lower and others whose specific gravity is higher than these limits. Pure kaolin has a specific gravity of from 2.4 to 2.6. Pure quartz sand has a specific gravity of from 2.5 to 2.8. Where clay is largely a mixture of varying proportions of these two minerals, its specific gravity is not far from 2.5. Clays containing in addition to these minerals mica and limonite are slightly heavier. The presence of magnetite, however, may greatly increase the specific gravity, while on the other hand organic matter may decrease it.

Methods of determining specific gravity are not uniform and different methods may produce different results in the same clay. By the use of the pycnometer the specific gravity of the individual grains is determined and taken as the specific gravity of the clay. By another method the specific gravity of lumps of clay which have been coated with paraffin is determined. This method considers the pore space a part of the clay. The specific gravity of any clay is less by the latter method.

COLOR.

The color of clays is an exceedingly variable property. Many shades and tints are represented. The color may be due either to the presence of organic matter or to the presence of iron and manganese compound. Shades of red, buff or brown are generally due to the presence of iron oxides. Blue and dark colors are sometimes caused by the presence of iron carbonate or of organic matter. White clays are devoid of susceptible coloring matter, but some white clays have color developed by burning.

By the color of the raw clay it is not possible to predict the color of the burned product unless the nature of the coloring matter and its amount are known. Some white clays contain enough iron to produce a dark shade when burned in an oxidizing flame. Titanium may produce a purple tint when the clay is burned at a high tempera-

ture. Some black clays are found to be very white after burning. The dark coloring matter in many clays is organic matter which is burned out, leaving the product white. Some yellow or red clays containing an excess of iron may burn to an iron black.

The color to which a clay will burn often has an important bearing on its value. A clay which may be of high value as a stoneware clay, for instance, may be entirely useless as a whiteware clay, because of the presence of coloring matter which would develop dark shades or splotches during burning. Even in common brick clays the color is of importance. The nearly colorless Milwaukee brick clay is of greater commercial value than the more common red or yellow burning clays. The most satisfactory test to determine the color of the burned product is to subject a sample of the clay to the same conditions of temperature to which the proposed ware is to be subjected. The shades of the burned clay are almost as variable as the natural clay.

The oxidation of iron compounds in the clay produces light reds, cherry reds, dark reds, chocolates and iron blacks, the latter being produced by an excessive amount of iron. Clays may contain a considerable quantity of iron and still be white or yellow. Vitrified wares contain iron silicates which may give a green, brown or black color. Spots on white, yellow or red wares are produced by sprinkling the surface of the clay product with iron or manganese particles. The oxidation or reduction of these particles produce black, brown or red specks on the wares.

HARDNESS.

The property by virtue of which one mineral is able to scratch another mineral is called hardness. Clays are soft rocks. They usually range in the scale of hardness from one to three. The maximum degree of hardness is represented in the flint clays while the minimum degree is attained in the chalk-like kaolin. This property refers to the ease with which the rock may be scratched. The individual particles in a clay may be a great deal harder than the rock. For instance, the quartz would have a hardness of seven, while the feldspar would have a hardness of six. Kaolinite has a hardness varying from 1 to 2.5.

Burnt clay has a much higher degree of hardness than raw clay. Vitrified clay products reach a hardness equal to that of quartz,

which will readily scratch glass. Hardness is a property very essential in all clay wares which are to be subjected to abrasion, as are paving brick; or to compression, as are building brick; or to chemical action, as are sewer pipe.

FEEL.

Clay containing particles of sand are harsh or gritty to the touch. The grit in some clays may be detected by rubbing the clay between the fingers. In other clays the grit can only be detected by moistening the clay between the teeth. Clays having a large percentage of clay base are smooth to the touch. Kaolin is somewhat like talc or soapstone to the touch. It is a very common practice for people to refer to an unctuous clay or shale as a soapstone. These clays may be shaved with a knife to a perfectly smooth surface, while a clay containing grit will have minute pits upon its surface where the blade of the knife has pulled out the sand grains. The moistened surface of the unctuous clay feels greasy or soapy. As a general rule the gritty clays are the least plastic and are called "lean" or "short" clays, while the more unctuous clays are the more plastic and are called "fat" clays.

ODOR.

The odor which emanates from the moistened surface of clay is distinct and characteristic. A very similar odor is given by the surface of some minerals when they are rubbed, and they are said to have an argillaceous odor. Some clays containing decaying organic matter have a fetid odor. Some very silicious clays contain such a small amount of clay substance that the argillaceous odor is not distinct. Some clays containing a very high per cent of clay substance do not give off an argillaceous odor. Therefore, this property cannot be counted a safe guide to the amount of clay substance.

TASTE.

The presence of certain soluble salts in clay may be detected by tasting the clay. Common salt, alum and ferrous sulphate are not infreqeuntly detected in this way. Clay prospectors sometimes place clay between the teeth in order to determine its proportion of sandy matter. They also employ this method to determine the texture and degree of plasticity.

SLAKING.

The crumbling of a clay under the action of water is termed slaking. When a clay slakes it breaks up into small fragments.

Slaking takes place wherever an air-dried clay surface is exposed to the action of water. The size of clay fragments or grains into which the clay mass is separated is fairly uniform for the same clay, but varies greatly in different clays. The shape of the particles is variable. Some are flat, some cubical, others irregular. As the particles of the clay separate they absorb water and increase in size.

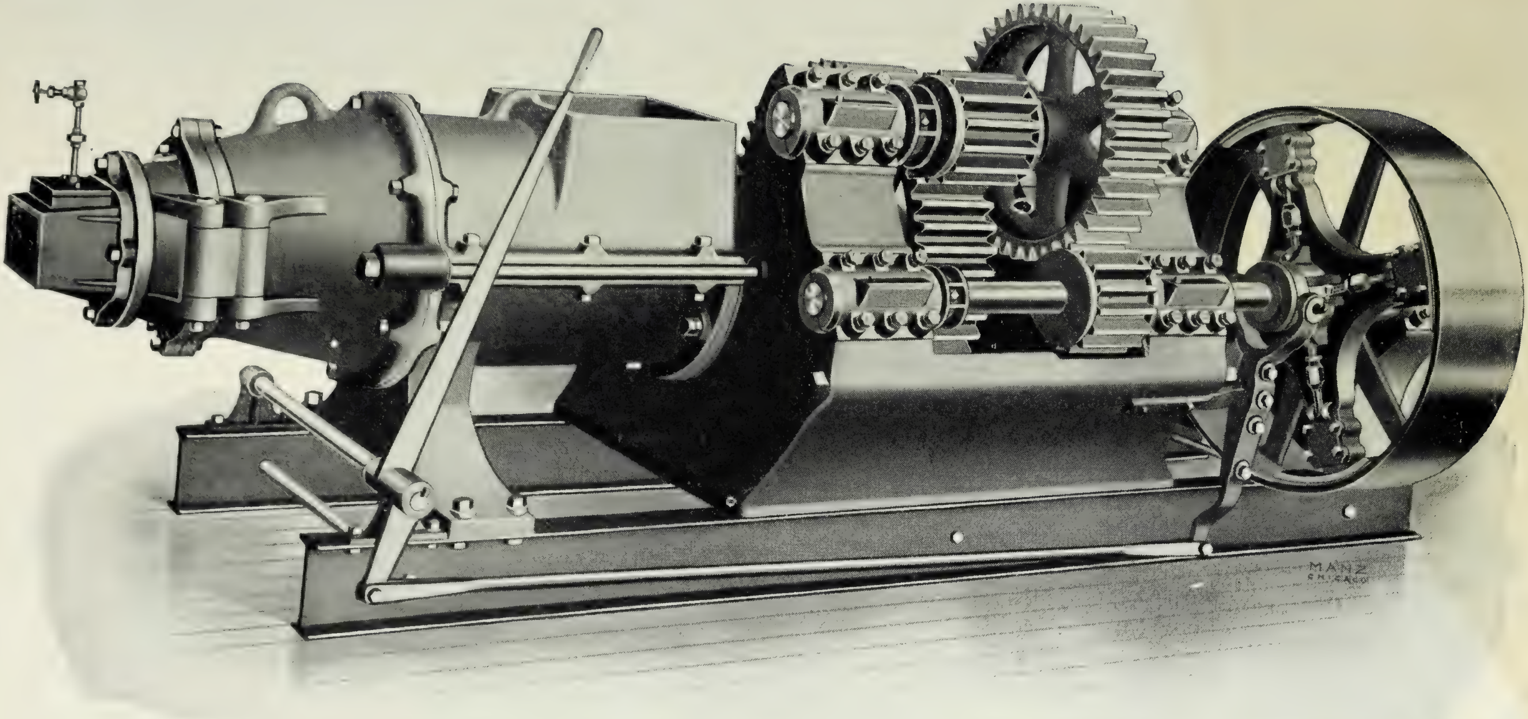
The speed of slaking varies in different clays. Clays of marked density, such as shale and flint clays, slake very slowly while the leaner surface clays slake very rapidly. Wet or puddled clays do not slake as rapidly as air-dried clay to which water is suddenly applied. The speed of slaking is determined by taking samples of natural clays of equal size and placing them in water and by observing the time elapsing until they are completely crumbled. A cube one inch in diameter of a lean loess clay from Grenada, Grenada County, was completely separated in less than ten minutes, while a shale from Mingo, Tishomingo County, was little affected after remaining in water one week.

Clays having a high slaking speed are usually very lean or sandy. The loess clays and the more silicious alluvial clays are of this type. The Porter's Creek (Flatwoods) and the "buckshot" alluvial clays have a slow slaking speed. The Tuscaloosa clays and the Wilcox (La Grange) clays slake rapidly. Clays used for any purpose requiring molding without grinding ought to possess at least a moderate slaking speed. A clay possessing a low slaking speed causes loss of time when tempered either in the wet pan or the pug mill. Such clays must be pulverized in the disintegrator and the granulator before they can be tempered and molded. The bottom clay in most of the surface deposits of the State has a slow slaking speed, and a tendency to form clods, which cannot be entirely removed in the short pug mills in use. For this reason the more successful brick plants are employing the use of one or more forms of pulverizers.

PLASTICITY.

A clay is plastic when it can be easily fashioned by the hands into a desired form, and when it has the property of retaining that form when so fashioned. Dry clay of any form is devoid of plasticity. In order that a clay may become plastic, it must be mixed with a certain amount of water. The quantity of water necessary

Plate IV.



STIFF-MUD BRICK MACHINE OF THE AUGER TYPE.

to plasticity varies with the physical condition of the clay. Not all clays become plastic when mixed with water. This fact leads to the conclusion that some clays possess an inherent property which renders them plastic by the addition of a certain proportion of water. Experience demonstrates that the plasticity of a clay is not due to a single condition, but that it results from the combined action of a group of factors. Some of these factors are well known, such, for instance, as the presence of uncombined water. There are others, however the nature of which is little known.

FACTORS OF PLASTICITY.

The factors which seem to have the greatest influence upon the plasticity of clay are:

1. *Fineness of Grain.*—Some clays which are non-plastic when taken from the pit, slaked and mixed with water, may be made plastic by reducing them to minute particles before mixing with water. In a similar way the plasticity of all clays may be increased. Fineness of grain is not the only essential factor, however. Some clays of exceedingly fine grain may possess but little plasticity. Experiments have been performed with glass, quartz, mica, limestone and talc to determine whether mere fineness of grain was sufficient to account for plasticity. The results were negative in each case. These substances could not be brought to a condition which would permit them to be molded into forms that would retain their shape.

2. *The Presence of Uncombined Water.*—As has been stated above, a dry clay is not at all plastic but it may become highly plastic when mixed with a certain amount of water. The water acts as a lubricant between the clay particles and thereby permits greater freedom of movement. At the same time the surface tension of the water holds the particles and permits a movement of the clay particles without interrupting the continuity of the clay mass. An effect to be compared to the stretch of a rubber.

3. *The Presence of Combined Water, Bacteria or Some Substance or Condition Which May be Destroyed by Calcining.*—When a plastic clay has been subjected to a temperature sufficient to drive off its combined water it is rendered non-plastic. Nor can its plasticity be

restored by reducing it to fine powder and mixing it with water. This fact proves that some important factor of plasticity has been destroyed by heating the clay. It has been found by practical tests that the plasticity of a clay is increased by "ageing," "mellowing," or "curing" the clay. These are terms applied to the same process which consists in storing the clay for a period of time in a damp cool place. For instance clay which has been stored for a time in a damp cellar is found to have an increased plasticity. This increase is thought to be due to the action of bacteria working in the clay. It is found also that the plasticity of a clay may be increased by the addition of tannin or the addition of an emulsion of straw.

4. *The Presence of Flat and Interlocking Crystals.**—The presence of flat crystals aid by increasing the amount of surface tension of the hydroscopic moisture. This does not apply to the large macroscopic plates of mica which sometimes occur in clay in such abundance as to be detrimental to its plasticity. Crystals which are curved or have angles or serrated edges present interlocking surfaces which increase the tensile strength of the clay and may also increase the plasticity.

A number of methods of determining the degree of plasticity of a clay has been suggested, but none are entirely satisfactory. The old method of determination by hand moulding is still the most reliable.

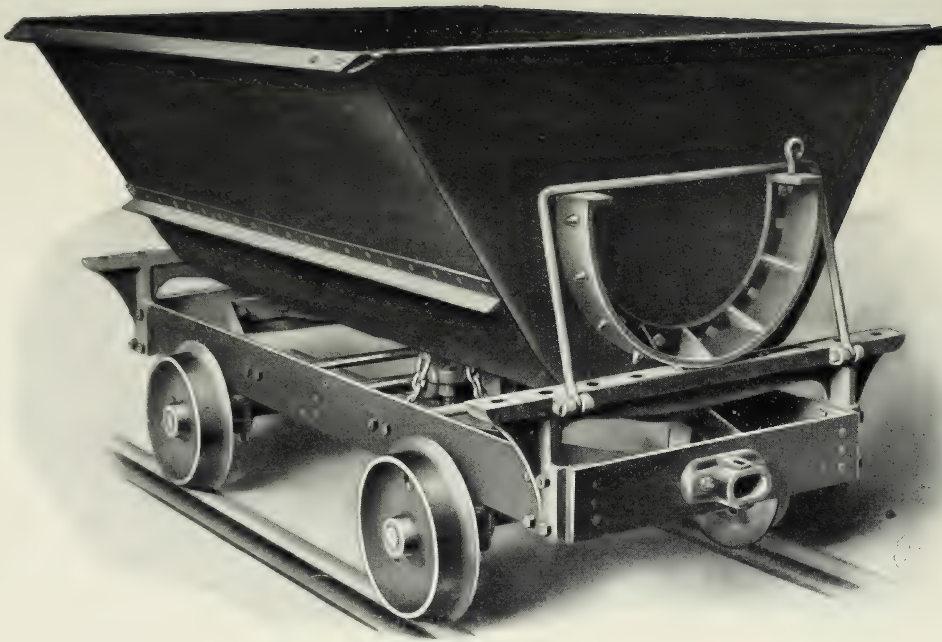
FUSIBILITY.

Matter may exist in three states, viz., solid, liquid or gas. Water, for example, at ordinary temperatures exists as a liquid. At slightly lower temperatures, it becomes a solid. At higher temperatures, it assumes the form of a gas. When in the solid state if heat be applied the solid becomes a liquid. This transformation is termed fusion. The temperature at which the solid becomes liquid is called the fusion point of the substance. The fusion point of any substance is controlled by pressure. All solids, having a definite chemical composition under a fixed pressure, fuse at a certain definite temperature. This definite temperature is called the fusion point.

Ordinary clays, however, are not of definite chemical composition. Clays are composed of a variety of minerals, each having a definite chemical composition and a definite point of fusion. When heat is

*See Mo. Geol. Survey, Vol. XI, p. 101.

Plate V.



EITHER-SIDE ROCKER DUMP CAR.

applied to this aggregate of minerals, the one having the lowest fusion point will be the first to fuse. The molten matter which is free to combine may unite with some other mineral or minerals in the clay and form a compound having a lower fusion point than the original compounds. These when molten may act as fluxes for other minerals and the whole clay be reduced to a molten condition at a temperature considerably lower than the fusion point of its most refractory constituents. The change from the solid to the liquid involves the consumption of heat in raising the temperature of the solid to the fusion point. Some heat is consumed as latent heat, some in chemical reactions.

Three stages are usually recognized in the fusion of a clay, namely: incipient fusion, vitrification and viscosity (Wheeler). In the first stage the more fusible particles become soft and upon cooling cement together the more refractory particles, forming a hard mass. In the second stage the clay particles become soft enough to close up all of the pore spaces so that further shrinkage is impossible. When the mass becomes cool, it forms a dense solid body which is glassy on a fractured surface. In the third stage, the clay body becomes so soft as to no longer retain its shape, and flows.

The fusibility of a clay depends on a number of factors, but the most important ones are the amount and kinds of fluxing impurities in the clay and the fineness of the grain.

For determining the temperature of kilns and furnaces and the fusion points of different substances, pyrometers of various kinds are used. One of these is the thermo-electric pyrometer. It consists of a thermo-electric couple which generates an electric current when heated. The intensity of the current increases with the temperature. The current is measured by means of a galvanometer. The thermopile consists of a platinum wire, and a wire composed of 90 per cent platinum and 10 per cent of rhodium. These wires, protected by clay tubes, are inserted into the furnace usually through a small opening in the door.

The fusibility of clays is also determined by the use of Seger cones. These cones are made of a mixture of substances of known fusibility. The cones, together with the clay to be tested, are placed in a furnace or oven and the heat applied. The cone which loses its shape at the moment the clay does determines the fusion point of the clay.

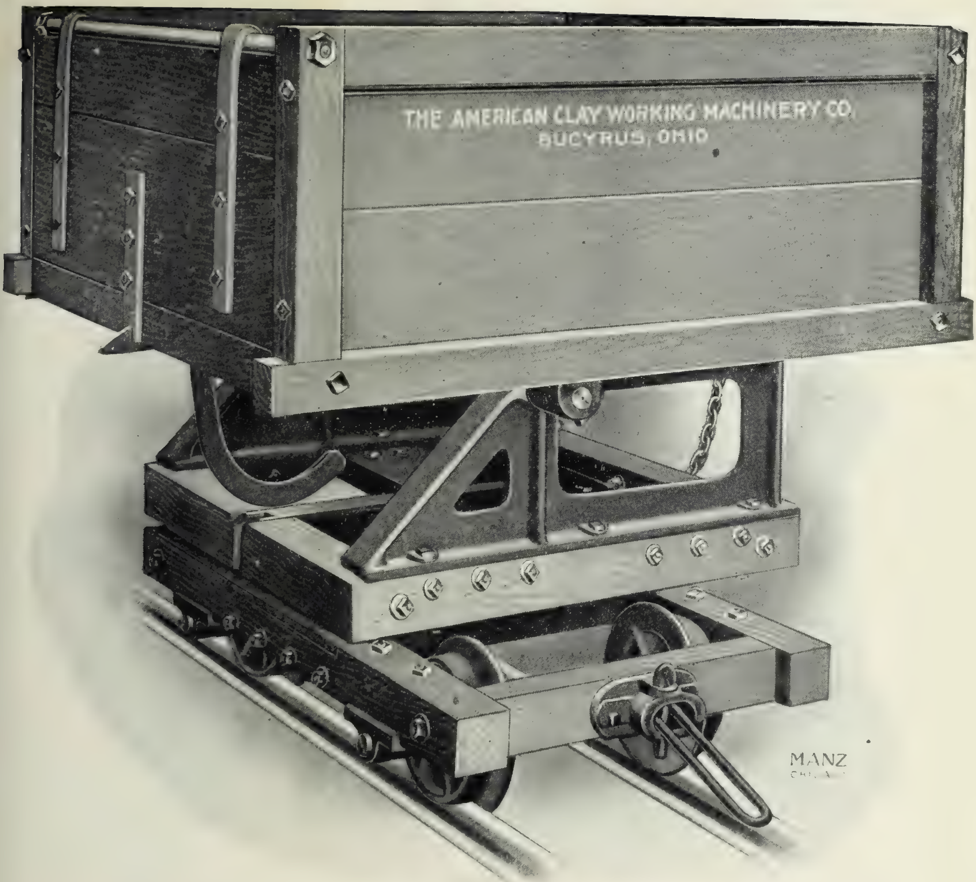
The cones are arranged in a series as given in the following table:

TABLE 10.

COMPOSITION AND FUSING POINTS OF SEGER CONES.

No. of Cone	*Composition*			*Fusing Point* °F	°C
022	0.5 NA_2O.... 0.5 P_2O_5.....		2.0 SiO_2.......... 1.0 BO..........	1,094	590
021	0.5 Na_2O.. 0.5 PbO......	0.1 Al_2O_3.	2.2 SiO_2......... 1.0 BO..........	1,148	620
020	0.5 Na_2O...... 0.5 PbO.......	0.2 Al_2O_3.	2.4 SiO_2......... 1.0 BO..........	1,202	650
019	0.5 Na_2O...... 0.5 PbO.......	0.3 Al_2O_3.	2.6 SiO_2......... 1.0 BO..........	1,256	680
018	0.5 Na_2O..... 0.5 PbO......	0.4 Al_2O_3	2.8 SiO_2......... 1.0 BO..........	1,310	710
017	0.5 Na_2O..... 0.5 PbO......	0.5 Al_2O_3.	3.0 SiO_2......... 1.0 BO..........	1,364	740
016	0.5 Na_2O...... 0.5 PbO.......	0.55 Al_2O_3.	3.1 SiO_2......... 1.0 BO..........	1,418	770
015	0.5 Na_2O...... 0.5 PbO......	0.6 Al_2O_3.	3.2 SiO_2......... 1.0 BO..........	1,472	800
014	0.5 Na_2O..... 0.5 PbO......	0.65 Al_2O_3.	3.3 SiO_2......... 1.0 BO..........	1,526	830
013	0.5 Na_2O..... 0.5 PbO.......	0.7 Al_2O_3.	3.4 SiO_2......... 1.0 BO..........	1,580	860
012	0.5 Na_2O..... 0.5 PbO.......	0.75 Al_2O_3.........	3.5 SiO_2......... 1.0 BO..........	1,634	890
011	0.5 Na_2O..... 0.5 PbO......	0.8 Al_2O_3.	3.6 SiO_2......... 1.0 BO..........	1,688	920
010	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3........ 0.3 Al_2O_3..........	3.50 SiO_2......... 0.50 BO..........	1,742	950
09	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.55 SiO_2......... 0.45 BO..........	1,778	970
08	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.60 SiO_2......... 0.40 BO..........	1,814	990
07	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.65 SiO_2......... 0.35 BO..........	1,850	1,010
06	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.70 SiO_2......... 0.30 BO..........	1,886	1,030
05	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.75 SiO_2......... 0.25 BO..........	1,922	1,050
04	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.80 SiO_2......... 0.20 BO..........	1,958	1,070
03	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.85 SiO_2......... 0.15 BO..........	1,994	1,090
02	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.90 SiO_2......... 0.10 BO..........	2,030	1,110
01	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3.......... 0.3 Al_2O_3..........	3.95 SiO_2......... 0.05 BO..........	2,066	1,130
1	0.3 K_2O........... 0.7 CaO...........	0.2 Fe_2O_3........ 0.3 Al_2O_3........	4.0 SiO_2...........	2,102	1,150
2	0.3 K_2O........... 0.7 CaO...........	0.1 Fe_2O_3........ 0.4 Al_2O_3........	4.0 SiO_2...........	2,138	1,170
3	0.3 K_2O........... 0.7 CaO...........	0.05 Fe_2O_3....... 0.45 Al_2O_3.......	4.0 SiO_2...........	2,174	1,190
4	0.3 K_2O........... 0.7 CaO...........	0.5 Al_2O_3..........	4.0 SiO_2...........	2,210	1,210
5	0.3 K_2O........... 0.7 CaO...........	0.5 Al_2O_3..........	5.0 SiO_2...........	2,246	1,230

Plate VI.



SWIVEL-DUMPING CLAY CAR.

TABLE 10—Continued.

COMPOSITION AND FUSING POINTS OF SEGER CONES—Continued.

No. of Cone	Composition			Fusing Point °F	Fusing Point °C
6	0.3 K_2O; 0.7 CaO	0.6 Al_2O_3	6.0 SiO_2	2,282	1,250
7	0.3 K_2O; 0.7 CaO	0.7 Al_2O_3	7.0 SiO_2	2,318	1,270
8	0.3 K_2O; 0.7 CaO	0.8 Al_2O_3	8.0 SiO_2	2,354	1,290
9	0.3 K_2O; 0.7 CaO	0.9 Al_2O_3	9.0 SiO_2	2,390	1,310
10	0.3 K_2O; 0.7 CaO	1.0 Al_2O_3	10.0 SiO_2	2,426	1,330
11	0.3 K_2O; 0.7 CaO	1.2 Al_2O_3	12.0 SiO_2	2,462	1,350
12	0.3 K_2O; 0.7 CaO	1.4 Al_2O_3	14.0 SiO_2	2,498	1,370
13	0.3 K_2O; 0.7 CaO	1.6 Al_2O_3	16.0 SiO_2	2,534	1,390
14	0.3 K_2O; 0.7 CaO	1.8 Al_2O_3	18.0 SiO_2	2,570	1,410
15	0.3 K_2O; 0.7 CaO	2.1 Al_2O_3	21.0 SiO_2	2,606	1,430
16	0.3 K_2O; 0.7 CaO	2.4 Al_2O_3	24.0 SiO_2	2,642	1,450
17	0.3 K_2O; 0.7 CaO	2.7 Al_2O_3	27.0 SiO_2	2,678	1,470
18	0.3 K_2O; 0.7 CaO	3.1 Al_2O_3	31.0 SiO_2	2,714	1,490
19	0.3 K_2O; 0.7 CaO	3.5 Al_2O_3	35.0 SiO_2	2,750	1,510
20	0.3 K_2O; 0.7 CaO	3.9 Al_2O_3	39.0 SiO_2	2,786	1,530
21	0.3 K_2O; 0.7 CaO	4.4 Al_2O_3	44.0 SiO_2	2,822	1,550
22	0.3 K_2O; 0.7 CaO	4.9 Al_2O_3	49.0 SiO_2	2,852	1,570
23	0.3 K_2O; 0.7 CaO	5.4 Al_2O_3	54.0 SiO_2	2,894	1,590
24	0.3 K_2O; 0.7 CaO	6.0 Al_2O_3	60.0 SiO_2	2,930	1,610
25	0.3 K_2O; 0.7 CaO	6.6 Al_2O_3	66.0 SiO_2	2,966	1,630
26	0.3 K_2O; 0.7 CaO	7.2 Al_2O_3	72.0 SiO_2	3,002	1,650
27	0.3 K_2O; 0.7 CaO	2.0 Al_2O_3	200.0 SiO_2	3,038	1,670
28	....	Al_2O_3	10.0 SiO_2	3,074	1,690
29	....	Al_2O_3	8.0 SiO_2	3,110	1,710
30	....	Al_2O_3	6.0 SiO_2	3,146	1,730
31	....	Al_2O_3	5.0 SiO_2	3,182	1,750
32	....	Al_2O_3	4.0 SiO_2	3,218	1,770
33	....	Al_2O_3	3.0 SiO_2	3,254	1,790
34	....	Al_2O_3	2.5 SiO_2	3,290	1,810
35	....	Al_2O_3	2.0 SiO_2	3,326	1,830
36	....	Al_2O_3	1.5 SiO_2	3,322	1,850

There are also some recording pyrometers in use. The Bristo recording pyrometer, according to the Iron Trade Review (Nov. 8 1906), consists of three distinct parts, viz., the recorder, which is located at the point most convenient for observation of the records, and for changing of the charts; the thermo-electric couple, the fire-end of which is to be inserted into the space where the temperature is to be measured; the leads, consisting of duplex flexible cable for making the electric connection between the records and the fire ends.

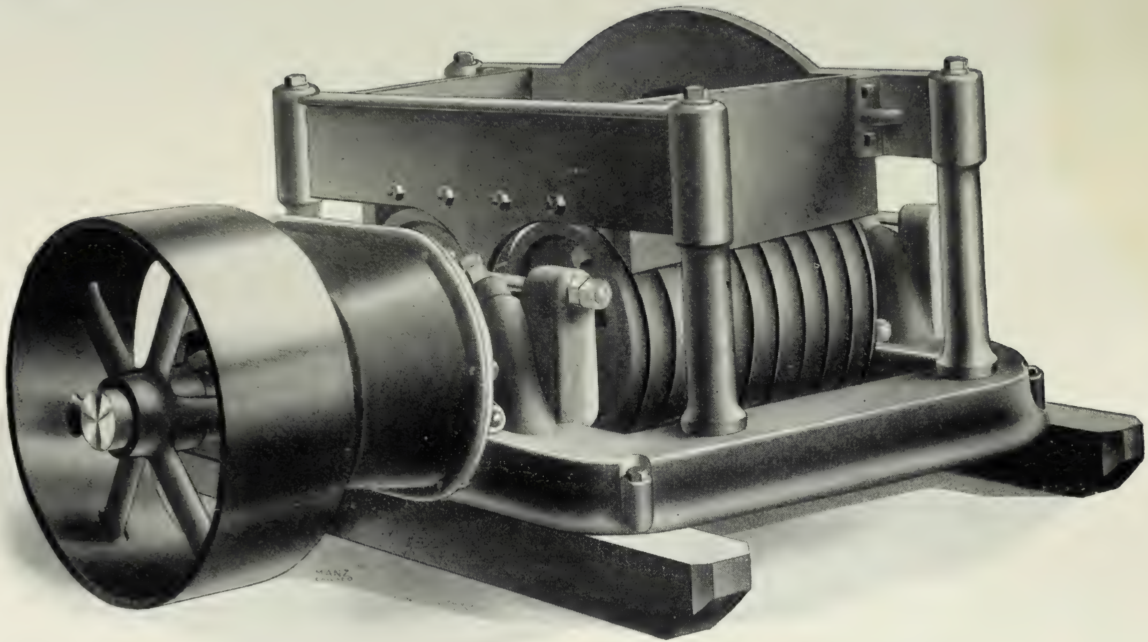
"The thermo-electric couple, which is located where the temperature is to be measured, produces a current of electricity, which is communicated to the recorder through the connecting leads. This current actuates a face, which is so sensitive that a record may be made upon it with a hair. When applied to the instrument, the chart is supported only over a portion of its surface by a semi-circular plate. The clock movement for revolving the chart is contained in the round case behind the semi-circular chart support, and is provided with an auxiliary attachment for periodically vibrating the unsupported portion of the chart, thus bringing the smoked surface into contact with the pointed end of the recorder arm at intervals of a few seconds. By this means, the record of its position is obtained and friction is eliminated.

"The series of marks made by this periodic contact of the recorder arm which removes the carbon from the chart, forms a continuous curve, unless the changes in temperature are extremely rapid. After the record of the day is completed the chart may be removed from the instrument and 'fixed' by immersion in a fixitive solution, which consists of gasoline or alcohol, to which has been added a small amount of concentrated fixitive. After fixing, the charts may be handled and filed without any danger of destroying the record.

"The simplicity of construction insures durability and permanent accuracy and makes the operation of the instrument an easy matter. The protecting case containing the galvanometer is hinged to the back of the recorder. This arrangement prevents injury to the recorder arm while the charts are being changed or the clock wound.

"It should be mentioned that the coating of lampblack on the charts is not sufficient to obscure the graduations, and the edges and center are unsmoked. The charts can therefore be conveniently

Plate VII.



CONICAL CORRUGATED CLAY CRUSHER.

handled and packed for shipment. The couples employed for ranges not exceeding 2,000 degrees Fahr. are made of special alloys, which are inexpensive, and may be of almost any desired form or length to suit the special requirements. For ranges above 2,000 degrees Fahr. the standard Le Chatelier platinum-rhodium elements are used. Compound couples may be used to reduce the high cost of the platinum-rhodium element. The inexpensive alloys employed for the extension of the couple are such that the two secondary thermoelectric effects at the junctions with the platinum and the platinum-rhodium elements neutralize each other if the temperature at these junctions does not exceed 1,200 degrees Fahr. The indications on the instrument will be the same as if the whole couple had been made of the more expensive metals. Where there are varying temperatures at the cold end of the couple, a mercury compensator is used, which automatically changes the resistance of the circuit, so that no connection is necessary for the working range of the instrument."

MECHANICAL ANALYSIS.

Clay is a mechanical mixture of mineral particles. These particles vary in size from those which are easily detected by the unaided eye to those which may be seen only by the use of a powerful microscope. The mechanical analysis of a clay consists in the separation of these particles into various groups. Because of the extreme degree of gradation in the size of the particles a complete separation is not possible, and it is not essential for the purposes of the clay worker.

In the mechanical analysis of soils the following methods of grouping have been employed and the same or similar grouping are applicable, and have been applied, in the separation of clays:

TABLE 11.

METHODS OF GROUPING IN MECHANICAL ANALYSIS.

No. of Group	*Hilgard*	*Hopkins*	*Osborne*	*Whitney*	*Name of Group*
1	3.0 m.m.	1.0 m.m.	3.0 m.m.	2.0 m.m.	Fine gravel
2	1.0 m.m.	.32 m.m.	1.0 m.m.	1.0 m.m.	Coarse sand
3	.5 m.m.	.1 m.m.	.5 m.m.	.5 m.m.	Medium sand
4	.3 m.m.	.032 m.	.25 m.m.	.25 m.m.	Fine sand
5	.16 m.m.	.01 m.m.	.05 m.m.	.01 m.m.	Very fine sand
6	.12 m.m.	.0032 m.	.01 m.m.	.05 m.m.	Silt
7	.072 m.	.001 m.		.005	Clay
8	.047 m.				
9	.036 m.				
10	.025 m.				
11	.016 m.				
12	.010 m.				

A number of methods of mechanical analyses has been employed. They may be classified under three heads, viz: the beaker or decantation method used by Osborne and others; the elutriation method of Hilgard, and the centrifugal method used by the United States Bureau of Soils. (See Bul. 24, U. S. Agric. Dept.)

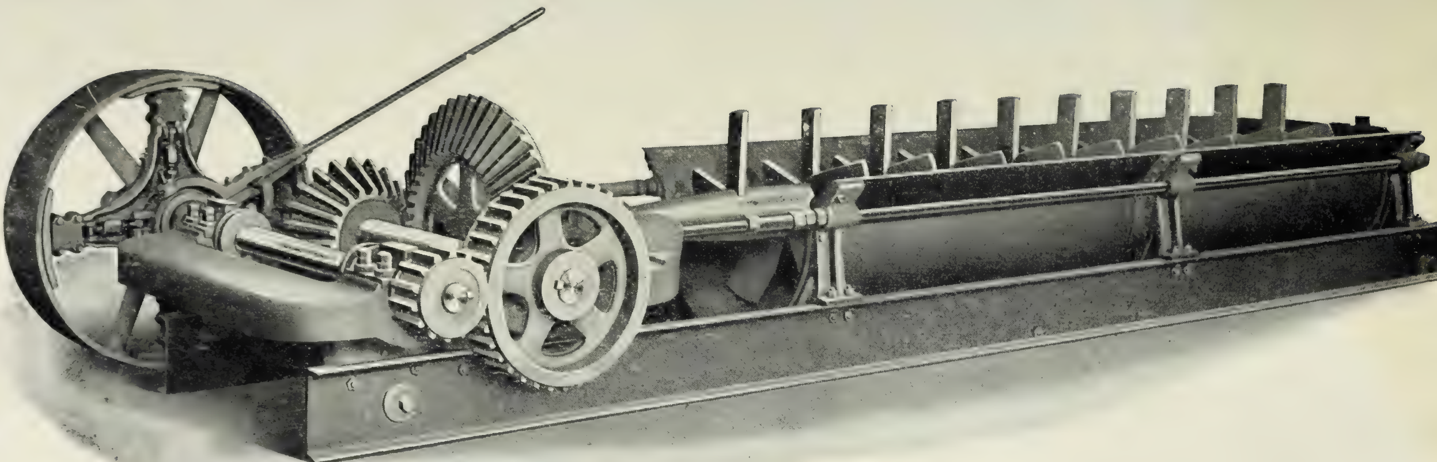
In the Osborne method of analysis the soil to be analyzed is placed in a cylinder containing water. After being agitated, the suspended particles are allowed to settle until only those of the smallest group remain in suspension. The water is then drawn off and the process is repeated until all the particles belonging to this group have been removed. Then the next larger group is removed. The water is evaporated, the particles dried and weighed and the per cent which they form of the whole determined. All of the groups of finer particles are removed in this way. The larger particles are separated by means of sieves.

Hilgard's elutriation consists of a vertical cylinder containing a rapidly revolving stirrer at the bottom. At the bottom a stream of water is forced through this cylinder at a given velocity. The size of the particles carried out by the current depends on the velocity of the current; *i. e.*, a velocity of 4 m.m. per second is sufficient to carry out all particles of quartz less than 0.25 m.m. in diameter, and a velocity of 64 m.m. per second would carry out particles 2 m.m. in diameter. The elutriatior is used for separating particles larger than 0.01 m.m. in diameter. The finer particles are separated by subsidence.

In the centrifugal method, the soil is first disintegrated by the use of a mechanical shaker, an instrument for shaking samples of soil in water, for a period of time sufficient to cause the complete separation of all aggregations of particles. The water containing the suspended particles of soil is then placed in the test tubes of a centrifugal machine. The machine is rotated until all of the coarse particles are thrown down. The particles of the finest group are decanted off. The process is repeated until only the coarser material remains and this is separated by the use of sieves.

By the use of a method suggested by Beyer and Williams (see Vol. XIV, Iowa Geol. Sur.) the mechanical analysis of a number of types of Mississippi clays was made with the following results:

Plate VIII.



HORIZONTAL GRANULATOR.

TABLE 12.

MECHANICAL ANALYSES OF MISSISSIPPI CLAYS.

		Per Cent						
Formation	*Locality*	*Fine Gravel*	*Coarse Sand*	*Medium Sand*	*Fine Sand*	*Very Fine Sand*	*Silt*	*Clay*
Brown loam	Jackson	0.0	0.5	0.2	10	5	60	22
Brown loam	Yazoo	0.0	0.5	0.3	2	4	75	15
Lafayette	Newton	0.5	2.0	12.0	53	8	20	5
Flatwoods	Bradley	...	2.0	3.0	10	50	13	10
Selma	Starkville	1.0	2.0	4.0	8	9	40	20
Alluvium (Buckshot)	Moorhead	0.0	0.2	1.0	2	2	58	30
Alluvium (Buckshot)	Greenwood	0.1	1.0	1.5	2	2	42	45

BONDING POWER.

The bonding power of a clay is its power to hold together particles of non-plastic materials. The bonding power of a clay is dependent in a measure on the amount of clay substance which the clay contains. It also depends on the size of the grain of the inert matter added. To illustrate, a larger amount of finely divided sand may be added to a clay without decreasing its plasticity and bonding power than of coarse sand. It is often necessary, in order to secure the proper shrinkage and drying capacity in a clay ware, to use a mixture of two clays or to add sand or grog to the clay. The quantity of the inert matter which may be added without seriously impairing the strength of the ware will depend on the bonding power of the clay. Bonding power is an essential property.

TENSILE STRENGTH.

The amount of resistance which a clay offers to pull is termed its tensile strength. Wet clays possess this property to a slight degree; dry clays to a greater degree, and burned clays to a still higher degree. Were it not for this property it would be impossible to handle clay ware because of the ease with which they would be cracked or broken. The tensile strength of a clay is not due to any chemical change but to the physical cohesion of its particles. It was formerly thought that the tensile strength of a clay was a safe guide to plasticity, but it is no longer so, for the reason that many very plastic clays have been found to have a very low tensile strength.

In preparing clay for the tensile strength test, the clay is first rolled or crushed in a mortar until it is in the condition of a powder.

Then in order to separate all particles of a certain maximum size, the powder is passed through a sieve. The sieve used in our experiments has only forty meshes to the inch. To this powdered clay water was added in sufficient quantity to form a plastic body. The wet clay was then molded in brass molds into brickettes. The form of the mold is seen in Figure 1.

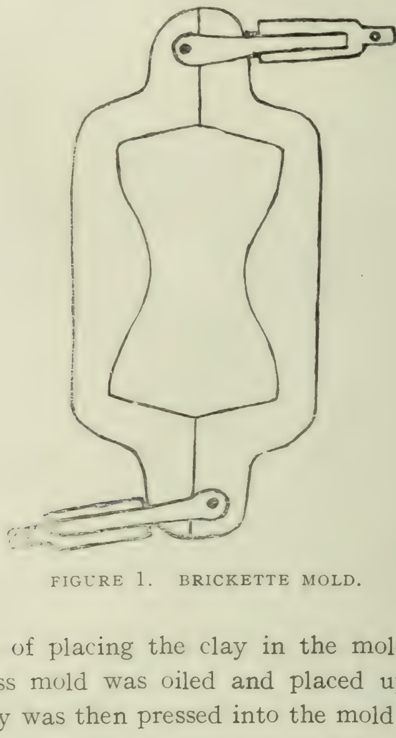


FIGURE 1. BRICKETTE MOLD.

Two methods of placing the clay in the molds were tried. In the first the brass mold was oiled and placed upon an oiled glass surface. The clay was then pressed into the mold by the fingers and by the use of a small wooden tamp cut to fit the mold. The clay was cut off on a level with the top of the mold by the use of a putty knife. By moistening the blade of the knife and passing it across the surface of the clay, both surfaces were made perfectly smooth. By the use of the tamp the clay was then pressed out of the mold upon an oiled glass surface. After remaining in this position for a couple of hours the brickettes were placed upon edge in order that both sides might dry equally. This is necessary in order to prevent cracking or warping. This method of molding was found unsatisfactory because of the difficulty in preventing laminations which would weaken the

PLATE IX.

REDUCTION MILL.

tensile strength of the brickette. Flaws due to air blebs were also produced.

By following a method of molding suggested by Orton* better results were obtained. The clay was now wedged into blocks about 3 inches long by $1\frac{1}{4}$ inches square. These blocks were now clamped into the molds and patted in until the clay completely filled the mold. The treatment from this point on was the same as in the other method. In the case of every brick prepared in this way the broken section of the brickette was found to be homogenous in structure. A number of clays were tested by both methods. The relative merits of the two methods may be determined from the following comparison of results obtained from tests made on a West Point brick clay. Twelve brickettes molded by the first method varied in tensile strength from 60 pounds per square inch to 151 pounds per square inch and the average tensile strength of the twelve was 144 pounds per square inch. Twelve brickettes molded by the second method varied in tensile strength from 122 pounds per square inch to 181 pounds per square inch and the average tensile strength of the twelve brickettes was 152 pounds per square inch.

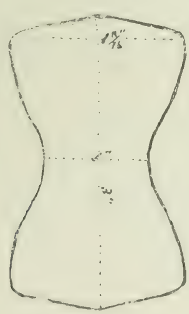


FIGURE 2. OUTLINE OF BRICKETTE.

The form of the brickette is shown in Figure 2. In its longest dimension it is three inches. The cross section of the brickette at the middle, if there is no shrinkage, is one square inch. The shoulders of the brickette have a width of 1 11-16 inches. The thickness of the brickette at any point is one inch, less the shrinkage. After air

*Transactions of Am. Cer. Soc., Vol. II, p. 110.

drying the brickettes were placed in an oven and the hygroscopic moisture driven out at the temperature of boiling water. The brickettes were then measured to obtain the amount of shrinkage.

The brickettes were tested by the use of a Fairbank's Cement Machine. The brickettes were placed in the clips of the machine and subjected to a gradually increasing tension. The increase of tension is secured by the weight of shot discharging into the pail on the lever arm. At the moment of breaking, the discharge of shot is stopped automatically. If the brickettes have undergone much shrinkage, they will not fit the clips of the machine and it will be necessary to bush them. This may be done by placing cardboard or blotter paper between the brickette and the clip.

The tensile strength is expressed in pounds per square inch and the shrinkage was calculated and taken into account in estimating the tensile strength of the brickettes.

In the majority of tests twelve brickettes of raw clay were tested, and twelve burned brickettes. The average of these twelve tests were taken. The results of these tests are found under the discussion of the physical properties of each clay.

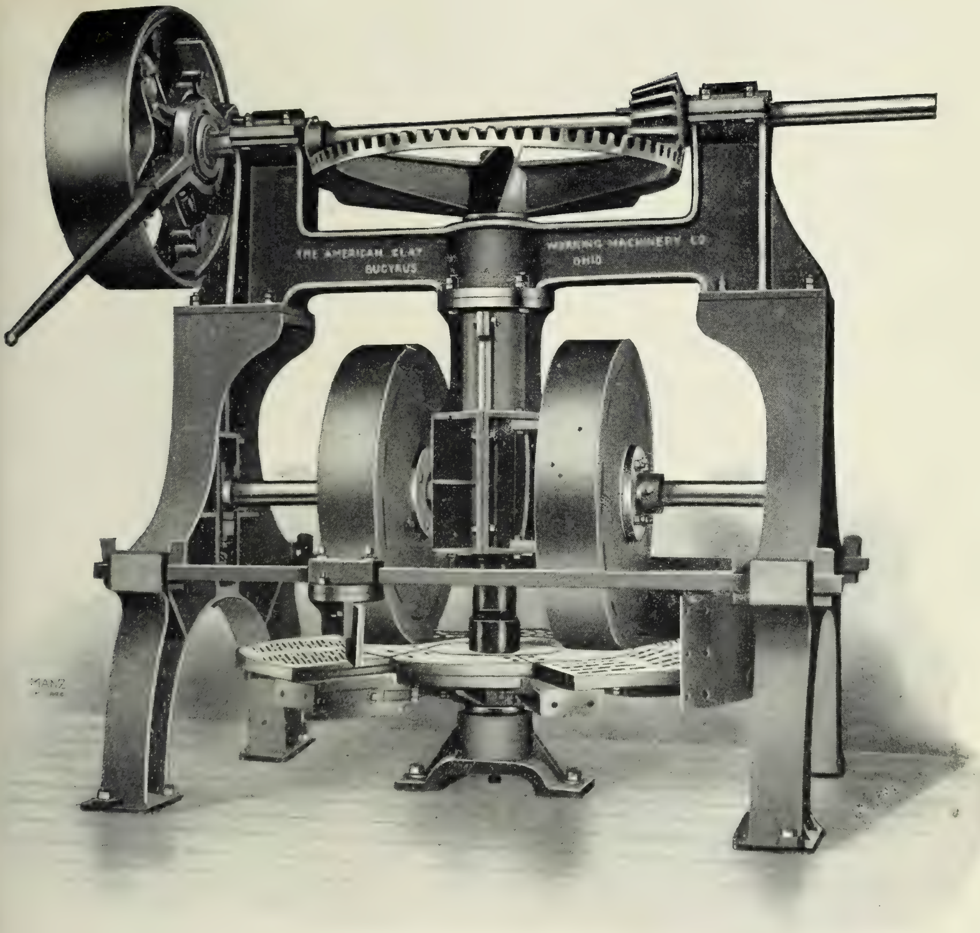
TABLE 13.

TENSILE STRENGTH OF MISSISSIPPI BRICK CLAYS.

Formation	*Tensile Strength in Pounds per Square Inch*	
	Raw Clay	*Burned Clay*
Yazoo alluvium ("buckshot" type)	188	484
Yazoo alluvium (sandy type)	90	157
Jackson residual clay	78	112
Lafayette	94	212
Flatwoods (Porter's Creek)	116	185
Selma residual	133	333
Buhrstone	187	181
Brown loam	78	133

The figures given in this table represent the average of a large number of tests made on brickettes molded from clay collected from a great many localities. The individual strength of these clays is given in the discussion of the physical properties of each clay. The brickettes tested in the burned condition were burned at a good red heat, but because of the differences in the clays all of the brickettes were not of equal hardness. Some of them exhibited a lower tensile strength than if they had been burned at a slightly higher tempera-

Plate X.



DRY PAN.

ture. The greater number of brickettes would have been classed as medium; a few were soft; none, however, were hard.

POROSITY.

A porous clay is one which contains considerable space not occupied by clay particles. This unoccupied space is called pore space and its volume depends on the size and shape of the clay particles. The maximum volume of pore space would be reached in a clay containing spherical grains of equal size. However, the shape and size of the grains in clays are extremely variable. The quartz grains are usually rounded, water-worn particles, but in some residual clays they are sharp angled. The mica grains are little flat crystals with irregular edges. The kaolinite may be flat or irregular in shape. The feldspar grains are either more or less rounded or irregular. The grains are in contact only at certain points, thus leaving spaces between the particles. These pores are in connection with other pores, and by a long chain of such connections irregular tubes are formed. These tubes are of capillary size, and the water which is within the clay may pass to the surface by capillarity.

Porosity is an important property in clays. The amount of water required for tempering the clay depends in a large measure on its porosity. The air-shrinkage of the clay is brought about by the loss of this water. The speed of tempering and the speed of drying depend on the porosity. The larger the pores the more readily the water is taken up and given off

CHAPTER IV.

PROCESSES OF CLAY MANUFACTURE.

MINING.

The method of mining clay for use in the manufacture of brick varies with the conditions under which the clay occurs and also with other conditions, such as the capacity of the plant. For example, drilling and blasting may be necessary in the mining of a hard shale, while undermining with pick and shovel may be used to great advantage in the mining of many of the incoherent surface clays.

Clays are mined either by surface diggings or by underground workings.

Underground mining may be conducted by the use of vertical shafts, through which the clay is usually brought to surface by the use of buckets attached by a rope to a windlass. If the clay should outcrop on the side or near the base of a hill, it may be mined by the use of drifts or by the use of tunnels.

The different methods of surface mining may be classed as the (1) pick and shovel method, (2) plow and scraper method, and (3) steam shovel method.

Pick and Shovel Method.--Usually the full thickness of the clay is exposed at once by digging a pit to the bottom of the clay bed. A sloping entrance to the pit is left on one side to facilitate hauling. If the clay be uniform in quality it is undermined near the base with a pick, causing the clay above to break off and thus securing the aid of gravity in the prosecution of the work. If there are two or more kinds of clay which it is desirable to mix, the upper layer may be removed for a short distance back, then the lower clay undermined. The two clays are thus kept separate and may be mixed in any desired proportion. In some clay pits nearly every spade length in depth represents a change in quality of clay, so that mining may be conducted on five or six levels. In many surface clays the upper portion of the bed is so sandy that it may be readily mined with the spade,

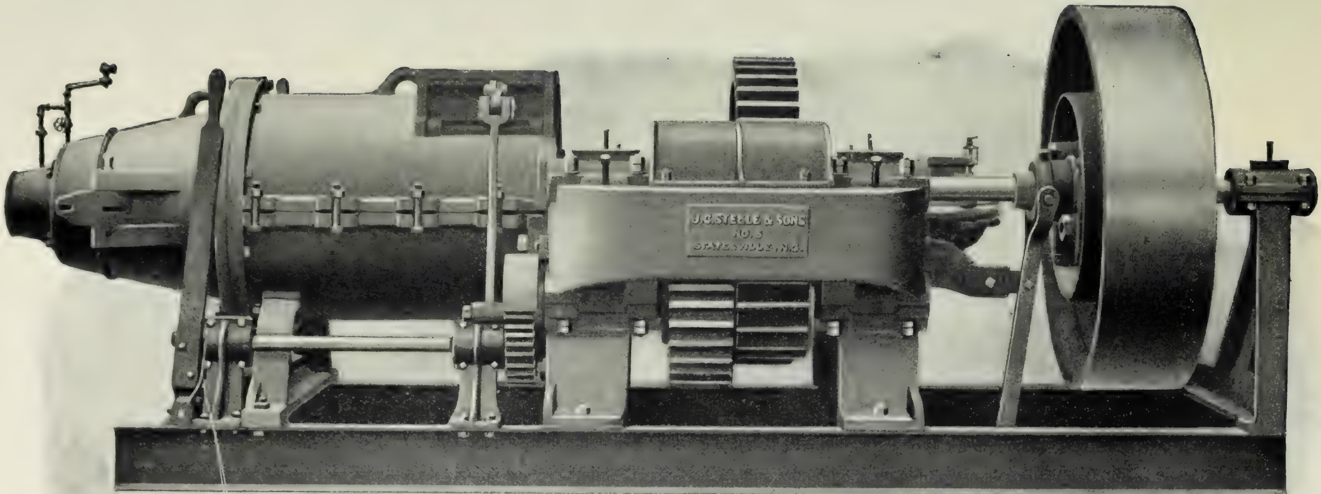
but the bottom clay may be a stiff joint clay which will require the use of pick and shovel.

Plow and Scraper Method.—The usual method of mining surface clays is by the use of the plow and scraper. The size of the plow and of the scraper, and the number of horses employed, depend on the capacity of the plant. The area of the proposed pit is first plowed and the soil removed. Then it is replowed and the clay taken either directly to the machine or to the mellowing shed, as the case may be, or it is taken to a dump and thrown into a car which is used to transport the clay to a shed or machine.

If the clay be uniform, this process of plowing and scraping may continue until the bottom of the clay stratum is reached. It frequently happens that there is a marked difference in quality between the clay in the top layers and that in the lower layers of the clay stratum. Under these circumstances the best results may be obtained only by mixing the top and bottom clays in certain proportions. In order to secure the proper mixture it may be necessary to remove the top layers from a portion of the pit. This top clay so removed may be placed convenient to the machine or the dump, so that it may be used later and the labor of its removal not wholly lost. The clay is now taken partly from the bottom layers and partly from the top in the proportion to give the best results. Usually the sides of the pit are kept sloping, so that the plow may cross the top clay diagonally, cross the bottom clay near the center of the pit and pass across the top clay again at the farther side.

Steam Shovel Method.—In plants of large capacity the steam shovel is employed in mining operations. Its use generally means a great economy in labor. The first cost makes it prohibitive for a plant of small size. To operate the steam shovel a track is laid on the bottom of the pit, and the clay scooped from top to bottom of the wall or face of the pit. The clay pit is usually enlarged in a semi-circle. The track upon which the shovel runs is laid parallel with the periphery and advanced as the wall advances. Inside of the steam shovel track is another track for the cars. When the shovel is loaded, a swinging crane moves it over the car. When in the proper position the bottom of the shovel is opened and the clay emptied into the car. The steam shovel of the dipper type has a radius of action of fifteen

Plate XI.



STIFF-MUD BRICK MACHINE, END CUT.

feet and greater. A cut is first made for a certain distance, extending to the bottom of the clay stratum. A track is laid upon the surface of the cut, and upon this track the steam shovel is placed. The shovel dips the clay from one bank and delivers it to cars on the opposite side. As the face of the cut advances, the track is moved forward and the clay removed from gradually increasing circles. The clay is well mixed, as the shovel takes clay from all parts of the face at each dip.

TRANSPORTATION.

A number of methods for the transportation of raw clay from the pit to the machine are employed. These may be classed as (1) wheelbarrow haulage, (2) cart haulage, (3) wagon haulage, (4) scraper haulage, (5) car haulage.

Wheelbarrow Haulage.—Wheelbarrows moved by hand power are employed to a very limited extent in some plants. Usually the plants are of small capacity, and the distance which the clay must be moved very short. Some large plants use wheelbarrows to transport clays from storage bins to pug mills.

Cart Haulage.—Hauling clay in a cart is not an uncommon way of transporting clays The carts are provided with two wheels, and are strongly constructed. They are usually drawn by one mule, though two mules hitched tandem are sometimes employed. The cart is provided with stout shafts and the harness is arranged so that the shafts may be tilted up and the clay dumped out at the rear end of the cart. This saves the labor of shoveling in unloading. The mule is generally driven by a boy who sits on the front end-board of the cart. The clay digger loads the carts, and a man may be employed to dump the carts as they come to the ring pit or pug mill. This method of haulage is not employed for great distances, and only on comparatively level ground.

Wagon Haulage.—Two-horse wagons are employed by some brick manufacturers. They are used where the distance from the plant to the pit is considerable, and the road rough. This is not an economical form of haulage for a plant of large capacity. Two-horse or four-horse wagons are also employed in transporting clay from railroad cars to the plant.

Scraper Haulage.—If the clay used is a surface clay and the pit easily accessible to the machine, two-horse drag scrapers may be employed to move the clay. They are also employed for loading the cars used by many plants.

Wheel scrapers are employed in many dry-press plants, in which it is desirable to store the clay in advance of use. Two horses are employed to draw them. The use of the scraper facilitates the mixing of the clay. It is very frequently desirable to mix a plastic clay and a non-plastic clay. A layer of one kind of clay is spread over the floor of the storing shed. This is covered with a layer of the other kind of clay, and the process repeated until the clay reaches the desired height in the shed. In using the clay, a section is taken from top to bottom of the stored clay. This method makes it possible to secure the proper proportion of each clay, and the mixing becomes more thorough in passing through the machinery.

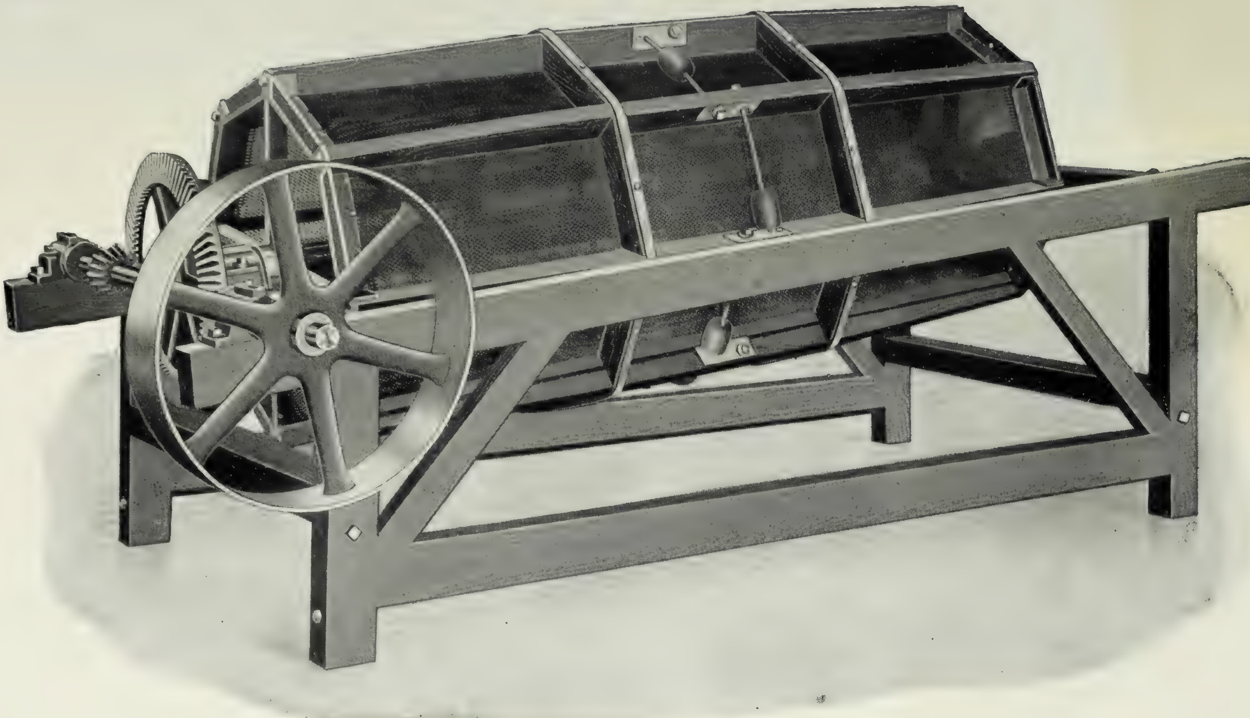
The clay gatherer is used in some plants. This is a cylindrical wheeled scraper which gathers the clay and transports it to the plant.

Car Haulage.—This form of haulage is used in nearly all plants of large daily capacity. The track consists of two parallel lines of wooden, or more often iron, rails of light weight laid on crossties. The rails vary in weight from 12 to 20 pounds, though it is generally not considered economy to use a rail lighter than 20 pounds, since the car wheels are worn so much more rapidly with the lighter rail. The ties are usually 4 x 4 or 4 x 5, oak or pine pieces. The cars used vary in capacity from one to three cubic yards. Most of the cars now in use have the boxes mounted on pivots so that they may be swung around and dumped from any position. They may be dumped forward, backward or to either side.

Selection of Timber for Tracks.—The selection of timber for the ties in the larger plants for the haulage track and the steam shovel track becomes an important matter. It is economy to select the most durable timber for such situations.

The durability of ties varies with the conditions. The kind of wood used is one of the determinative factors of its durability. Experiments tend to show that under like conditions different woods will last as follows:

PLATE XII.



ROTARY CLAY SCREEN OF THE OCTAGON FORM.

TABLE 14.

DURABILITY OF DIFFERENT WOODS.

Ash, beech and maple	4 years
Spruce, hemlock, red and black oaks	5 "
Elm and long leaf pine	6 "
Cherry, black walnut, locust and tamarack	7 "
White oak and chestnut oak	8 "
Chestnut	8 "
Black locust, cypress and red cedar	10 "
Redwood	12 "

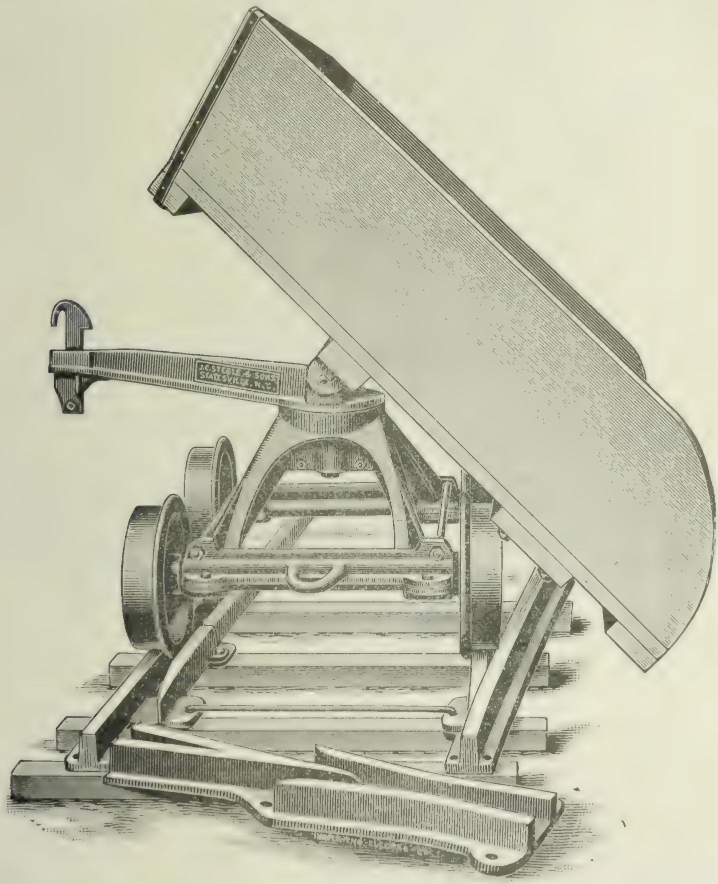


FIGURE 3. SIDE-DUMPING CLAY CAR.

Decay in wood is produced by the growth of forms called fungi. The conditions favorable to the growth of fungi are (1) abundant moisture, (2) an optimum temperature, and (3) the presence of air.

The optimum temperature for most species is about 80°F. Fungus decay may be prevented by keeping the timber dry, or at a temperature exceeding 100°F., or by immersing in water to exclude the air.

Such methods of destroying the conditions favorable to fungus growth are not practicable in the case of ties, and it becomes necessary to resort to some method of excluding the moisture. To accomplish this the timber is first kiln dried and then treated to an immersion in creosote, tar or paint, which prevents the entrance of moisture.

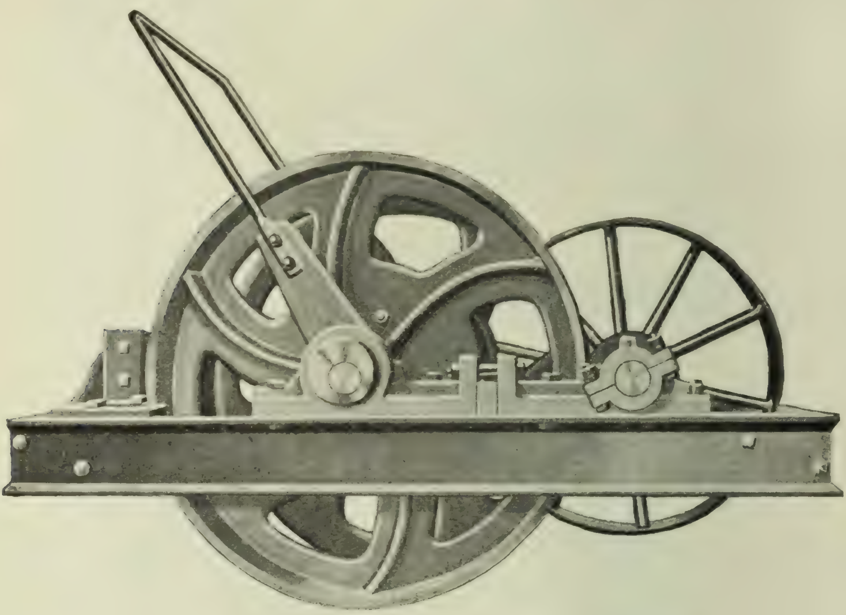
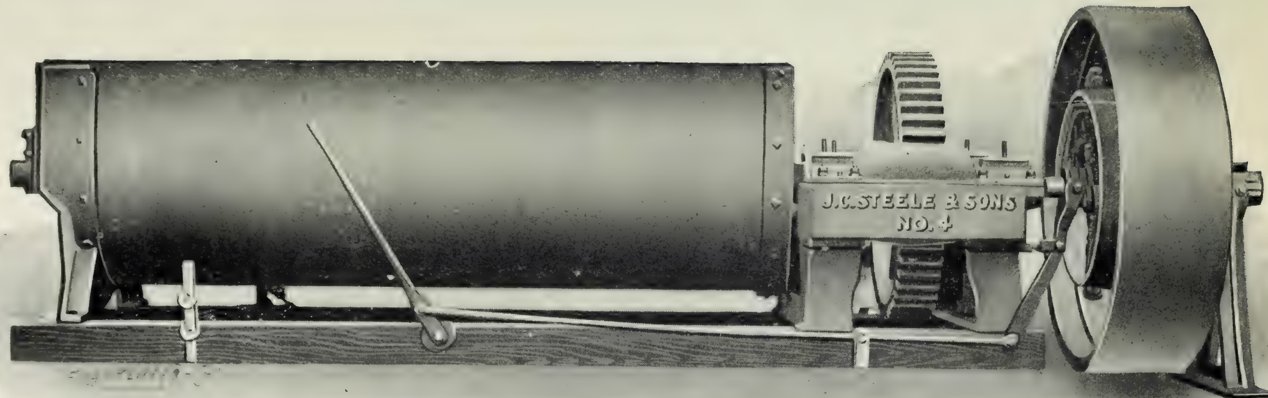


FIGURE 4. DOUBLE-FRICTION HOISTING DRUM.

Sap wood decays much more readily and rapidly than heart wood. This fact should be borne in mind when selecting timber for damp places. It should also be remembered that certain species are more durable than others. Timbers are sometimes preserved by steaming to open the pores, and then forcing a combination of bichloride of zinc and of creosote into the pores under pressure. These substances "poison" the wood so that the fungi cannot feed upon it. The longevity of the wood may thus be increased two or three fold.

PLATE XIII.



PUG MILL.

GRINDING.

Clays are reduced to a pulverulent or granular form by the use of a variety of machines. The following names are applied to such machines: crushers, rolls, disintegrators, granulators, pulverizers, dry pans, ball machines and reduction mills. For some of these to do effective work the clay must be thoroughly air-dried, but some of them may be used for pulverizing damp clay.

Crushers.—Jaw crushers are employed for breaking up indurated clays or shales. They contain a pair of movable jaws between which the clay is crushed. These jaws open wide at the top, and gradually close in as the bottom is approached. Another type has a stationery jaw in the shape of an inverted hollow cone in which a conical movable jaw works upon a pivot with an up-and-down movement alternately widening and narrowing the space between the jaws. (See Plate VII.)

Rolls.—Rolls consist of two or more iron or steel cylinders of rolls between which the clay is crushed. In some machines there are two cylinders which are made to revolve in opposite directions. The clay is fed into a hopper on the upper side of the rolls, and is crushed as it passes between the rolls. In some machines two small cylinders are placed above two large ones. The space between the top cylinders is greater than that between the large ones. The rolls run at different speeds, one having twice or three times the speed of the other. The space between the rolls is regulated by having rubber or coil springs. The distance between the rolls may be regulated for different kinds of clay. The rolls are provided with scrapers for keeping them clean. The surface of the rolls may be smooth, corrugated, conical, toothed or conical and corrugated. The capacity varies from 1,000 to 5,000 bricks per hour. The speed of the rolls is ordinarily from 150 to 300 revolutions per minute.

Granulators.—Granulators are horizontal, semi-cylindrical shells in which a long shaft revolves centrally. To the shaft are attached knives for cutting and tearing the clay. The angle at which the knives are set upon the shaft determines the speed or movement of the clay through the granulator. The clay is fed into the rear end of the machine, and crushed and shoved forward by the knives. The knives are ground and polished to prevent the clay from sticking.

The speed of the knives is from 150 to 300 revolutions per minute. The capacity varies from 3,000 to 15,000 brick per hour.

Disintegrators.—Disintegrators may be used for handling dry or damp clay. (See Plate XVI.) The machine is provided with a large roller which moves at a low rate of speed, and feeds the clay to a smaller roller which is provided with steel cutters. The cutters may be replaced as they become worn. The disintegrating roller is moved at a high rate of speed, and the cutters strike the clay and break it up. The distance between the rollers is adjusted by moving the feed roller. The speed of the feed roller is 30 or 40 revolutions per minute, while that of the disintegrator roller is from 400 to 600.

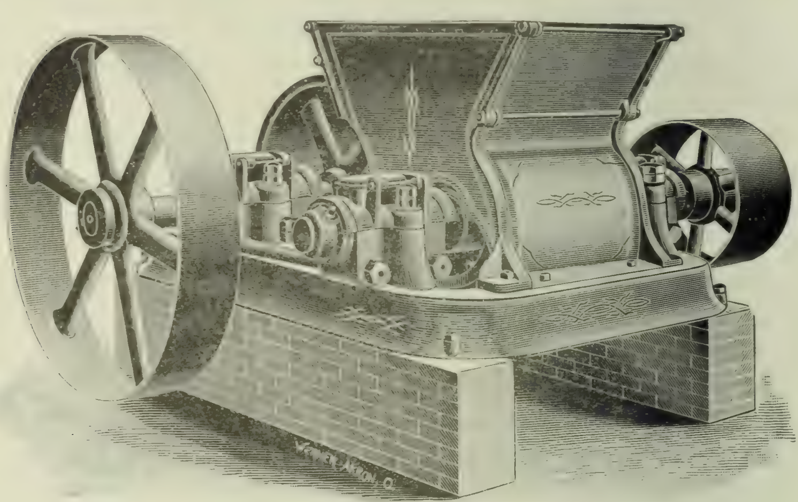


FIGURE 5. CLAY DISINTEGRATOR.

The combined disintegrator and pulverizer consist of "several oppositely revolving cages formed of round bars, reinforced with iron rings and secured to heavy cast circular discs. The bars of one set of cages project between the bars of the opposite cages. No grinding or crushing surface is presented; the material to be disintegrated is received into the inner cage, and by the centrifugal force created by the rapidly revolving cages, the material is projected through the cages and against each other." This action by force of impact breaks up the clay. The differential speed between the hopper side

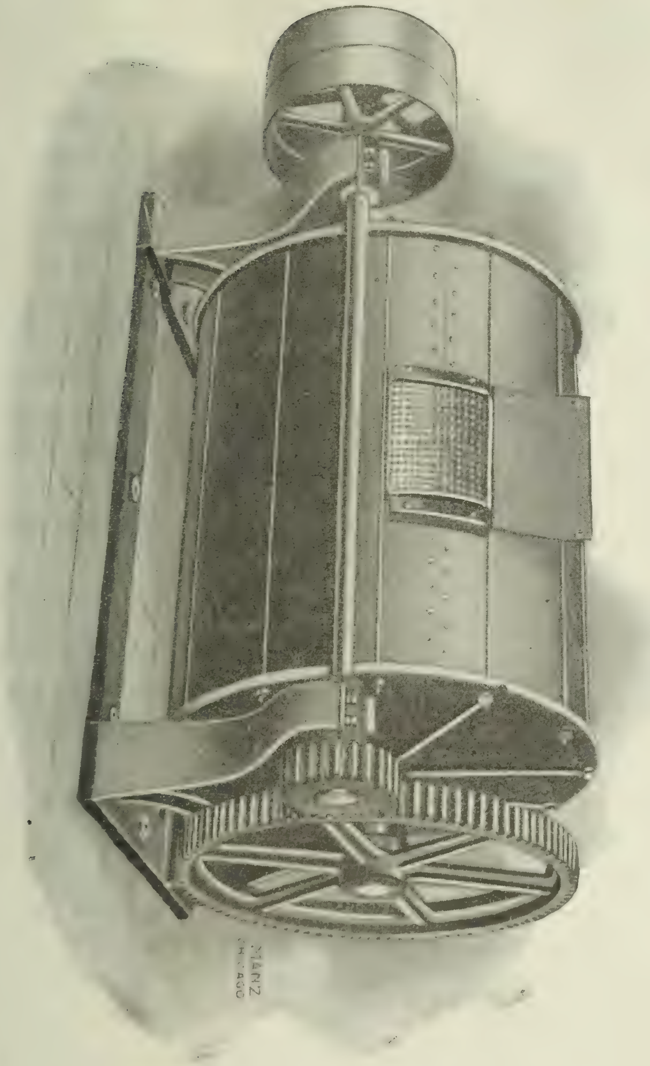


FIGURE 6. PEBBLE CYLINDER MACHINE.

and the opposite side is usually about 100 revolutions per minute. The capacity of the machines vary from 1,000 to 10,000 brick per hour. (See Figure 5 and Plate XVI.)

Reduction Mills.– Reduction mills are used for grinding dry clay. They consist of a cylindrical chamber with a perforated bottom plate. Above the bottom a perforated grinding plate revolves with a speed of from 300 to 600 revolutions per minute. The clay which is thrown upon the plate furnishes by its own weight the friction necessary for attrition. As the clay is pulverized, it drops through the perforations, or by centrifugal action is thrown out between the rings. (See Plate IX.)

Dry Pans.—Dry pans are used for pulverizing dry clays, grog, shales and other hard materials. They consist of revolving pans, containing two large rollers or wheels supported on horizontal axes. The pan is attached centrally to a vertical revolving shaft. The motion of the pan is conveyed to the wheels. The bottom of the pan in the path of the wheels is solid. The outer portion of the bottom is perforated. The pulverized clay, being thrown outward by centrifugal action, drops through the perforations. Scrapers traversing the bottom of the pan throw the clay in front of the wheels. The pans vary in diameter from 5 to 9 feet. The perforated bottom of the pan is generally made in sections which may be removed, and replaced by sections of different mesh. The wheels or mullers have tires which are removable, and may be renewed when badly worn. The space between the wheels and the bottom of the pan may be adjusted by the aid of springs and adjusting screws. The gearing and pulley shaft are generally placed at the top of the frame, which may consist either of wood or steel, but in large machines the latter is used almost exclusively. The machines vary in weight from two to fifteen tons. Dry pans are sometimes run in pairs, both pans being operated by the same pulley, the latter being on the center of the shaft with a pinion on each end. (See Plate X.)

Ball Mills.—Ball mills are sometimes employed for grinding fine grades of clay or glazes. They consist of a cylinder set in a frame, and revolved by means of a driving pulley, attached by appropriate gearing. The clay is placed in the cylinder through an opening in one end of the cylinder. Hard flint pebbles or porcelain balls

are put into the cylinder, and as the cylinder revolves these strike the clay and pulverize it. When it has reached the proper degree of fineness, it leaves the cylinder through a perforated plate. In this type of ball mill, the action is continuous. In the periodic type, the clay is put in, and none removed until all has reached the proper degree of fineness.

TABLE 15.

CRUSHING MACHINERY USED IN MISSISSIPPI BRICK PLANTS.

1.	Number of plants using rolls	2
2.	" " " " disintegrators	20
3.	" " " " granulators	15
4.	" " " " dry pans	2
5.	" " " " reduction mills	0
6.	" " " " ball mills	0
7.	" " " " no separate crushers	41
	Total number of plants reporting	65

SCREENING.

Screens are used in few plants in this State outside of pressed brick plants. They are used in order that the pulverized clay may not contain particles larger than a certain maximum size. The perforated materials used in the screen may be either wire netting or perforated iron or steel plates.

Screens may be classed as rotary, inclined stationary, inclined vibratory or endless revolving.

Rotary Screens.—Rotary screens may be cylindrical, conical or polygonal. The screens are mounted in strong frames of heavy timber, within which they revolve. Some are provided with a short driving shaft to which a driving pulley is attached by gearing. Others do not have shafts, but the driving pulley is attached by a chain which passes around a cogged flange on the end of the screen. The screen is mounted on grooved trunions, a pair located at each end of the screen. The cylinders vary in length usually from 5 to 9 feet. The end of the screen opposite the gearing is elevated so that as the screen revolves the clay moves longitudinally through the screen. The tailings, material too coarse to pass through the perforations of the screen, pass out at the end of the screen, and are carried back to the grinder by means of a chute or other form of conveyor. The

fine clay drops through the screen into a bin below. The rotary screens are kept clean by means of metal brushes or some automatic jarring device. (See Plate XII.)

Inclined Stationary Screen.—The inclined stationary screen is in the form of an inclined floor over which the crushed clay passes under the influence of gravity. The inclination of the screen will determine the velocity of the clay and also the maximum size of grain of the screened clay. The lower the velocity of the clay the smaller the size of the largest particle passing the screen. If the screen be placed at a low degree of inclination, more of the clay will adhere to the surface of the screen. Sometimes a steam coil is placed on the under side of the screen to heat the screen, or prevent the clay from sticking to its surface. The pulverized clay drops through the screen into a bin, while the tailings are carried from the end of the screen back to the crusher.

Inclined Vibratory Screen.—The inclined vibratory screen has a much lower angle of inclination than the stationary, and for that reason requires a constant movement of the screen to aid in the movement of the clay across it. The vibratory movements may be either transverse or longitudinal. *"This movement is imparted by either an eccentric or crank. The clay is thrown on the screen, and if the impulse given to the screen be longitudinal, the clay is gradually carried downwards by repeated little jumps in the direction of vibration. If the vibration be transverse, the clay will be thrown from side to side, and will move to the lower end of the screen more slowly than in the former case. Within limits, the longer the time required for the clay to pass the length of the screen, the more perfectly will the screening be accomplished, and in all instances with this style of screen, the maximum size of the particles passing it is approximately the diameter of the mesh. It is recommended in the use of this class of screen that sufficient play be provided in the vibrating device that a brief pause is allowed at the extremity of each swing. There should be provided solid blocks or posts, against which the screen is brought to a sudden stop with each vibration. The repeated jar thus imparted with each swing is very effective in keeping the meshes open, especially if the clay happens to be damp."

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*Beyer and Williams, Geol. Sur. Iowa, An. Rept. XIV, 1903, p. 180.

Revolving Screen.—The revolving screen is made up of a large number of screen plates attached at the ends to two endless chains. The clay is delivered from a spout upon a spreading table from which it descends to the screen. As the screen is revolved, the screen plates move upward to meet the descending clay. The fine particles drop through the perforations in the plates, while the larger particles pass off the end of screen below. The plates are kept clean by a metallic brush-roller which is attached to the lower side of the screen, and removes the clay from the plates as they are brought beneath the frame.

Eleven plants in Mississippi, out of a total of 65 reporting, use some form of screen.

TEMPERING.

Clays are tempered either by the use of soak pit, ring pit, pug mills, wet pans or chasers.

Soak Pit.—The soak pit is employed in some soft mud plants. The pit consists of an excavation of rectangular area, into which the clay is thrown. Some pits have bare walls, others are provided with plank walls and bottom. In some plants four or five of these pits are located along a line in front of the drying shed or yard and the molding machine, which is placed upon trucks, is moved from pit to pit as the clay in one pit is exhausted. The time required for soaking depends on the texture, and the slaking power of the clay. The clay is usually allowed to remain in the pit at least twelve hours. In case it is to be used for hand molding, it is first "slashed out" with a spade, a process of mixing by hand power. If the clay is to be used in machine molding, it is thrown into the box of the machine where it is pugged before delivery to the molds. The clay and whatever non-plastic material, such as sand or sandy clay, is necessary, is placed in the pit and then wet down by water conducted to the pit by pipes from barrels, wells or reservoirs. There are not many soak pits used by Mississippi brick plants. Out of 65 plants, only 6 use the soak pit.

Ring Pit.—Ring pits are of two types, viz.; those operated by horse power and those operated by steam power. They are similar in form and general make, but differ in size and capacity. They vary in capacity from 8,000 to 30,000 bricks. The pit is circular in

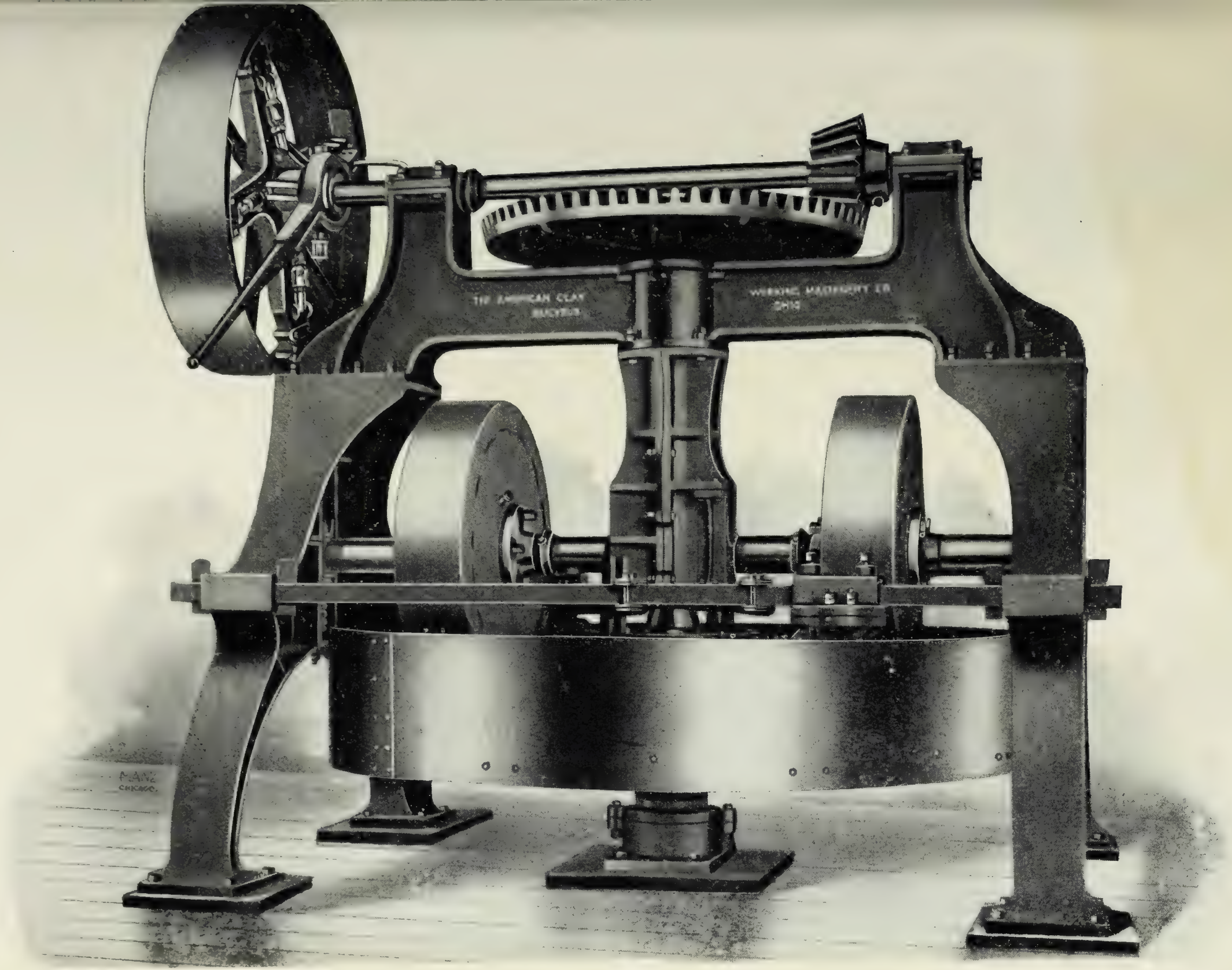
area and from 2 to 3 feet in depth. The mixer consists of a beam bearing a wheel, the former being attached at one end to a pivotal stake set in the center of the pit. The wheel, which is constructed of iron, has a diameter of about six feet. As the sweep is moved round the ring, the wheel revolves on the beam as an axis, and at the same time moves either outward to the periphery or inward toward the center of the pit, the direction being determined by its position at the start. By means of this alternating centripetal and centrifugal motion, every portion of the pit is traversed by the wheel and the clay thoroughly mixed.

The small size pit having a capacity of 8,000 bricks requires a two-horse team for operation. The time required for tempering in the ring pit varies with the clay used. The residual loess clays may be tempered in from two to three hours. These clays, however, slack very readily. With some clays it is necessary to use ring pits, so that the clay which is being tempered one day can be used by the molders the day following.

There are 9 plants out of 65 reporting which use the ring pit. These are all operated by horse power.

Pug Mill.—Pug mills are also used for tempering clay. Nearly every brick machine of soft-mud or stiff-mud type contains some provision for mixing the clay. In the soft-mud machine of the vertical type, the clay is pugged in the upper part of the machine, and then forced below into the molds. In the steam-power soft-mud machine a separate pug mill is employed. This consists of a semi-cylindrical chamber, open at the top, in which a horizontal shaft revolves. The shaft is provided with blades which cut up the clay, and mix it thoroughly. The clay enters the chamber at one end, is softened with water, and forced by the revolving blades toward the opposite end of the pug mill, where it is discharged into the molding chamber. The angle at which the blades are set on the shaft determines the speed at which the clay is discharged. For thorough mixing and high speed, the pug mill should be long, so that the clay may come in contact with a large number of blades. Ordinarily pug mills vary in length from 5 to 10 feet. (See Plates XIII and XV.)

In stiff-mud machines, sometimes only short pugging chambers are in direct connection with the molding chamber, and the clays are



WET PAN.

tempered and forced through the die by the revolutions of the same shaft. For the majority of clays in use in this State, this form of tempering is not advisable if the pugging is the only form of preparation given the clay before molding. In many plants the pug mill is the only crushing machinery used. It is expected not only to disintegrate the clay but to mix it as well. This cannot be accomplished in a small pug mill.

Wet Pan.—Wet pans are circular pans in which a pair of heavy iron wheels travel. The clay is placed in the pan, softened with water, and crushed and mixed by the movement of the wheels between the bottom of the pan and the surface of the wheels. Wet pans are not commonly employed in brick plants. They may be employed to advantage in potteries or fire-brick plants. (See Plate XIV.)

The "chaser" used in some potteries consists of a wooden or iron wheel which revolves in a circular path on a floor and crushes and mixes the clay.

TABLE 16.

SUMMARY OF TEMPERING MACHINERY USED IN MISSISSIPPI BRICK PLANTS.

Number of yards using soak pits	6
" " " " ring pits	9
" " " " separate pug mills	17
" " " " wet pans	0
" " " " chasers	0
" " " " no separate tempering machinery	33
Total number of yards reporting	65

MOLDING.

Clay which is molded into brick may be used as a soft mud, a stiff mud, as dry or semi-dry clay. The methods of molding clays into brick may be classed according to the following grouping:

- Soft-mud process.
  - Hand molding.
  - Machine molding.
    - Horse power.
    - Steam power.
- Stiff-mud process.
  - Plunger type machine.
  - Auger type machine.
- Repressing brick.
- Dry press process.
  - Hydraulic power.
  - Steam power.

In some plants two or more methods of molding are employed. They may manufacture soft-mud brick, stiff-mud brick and dry-pressed brick. Very few clays are adapted to all methods of manufacture. A sandy type of clay is better adapted to the soft-mud

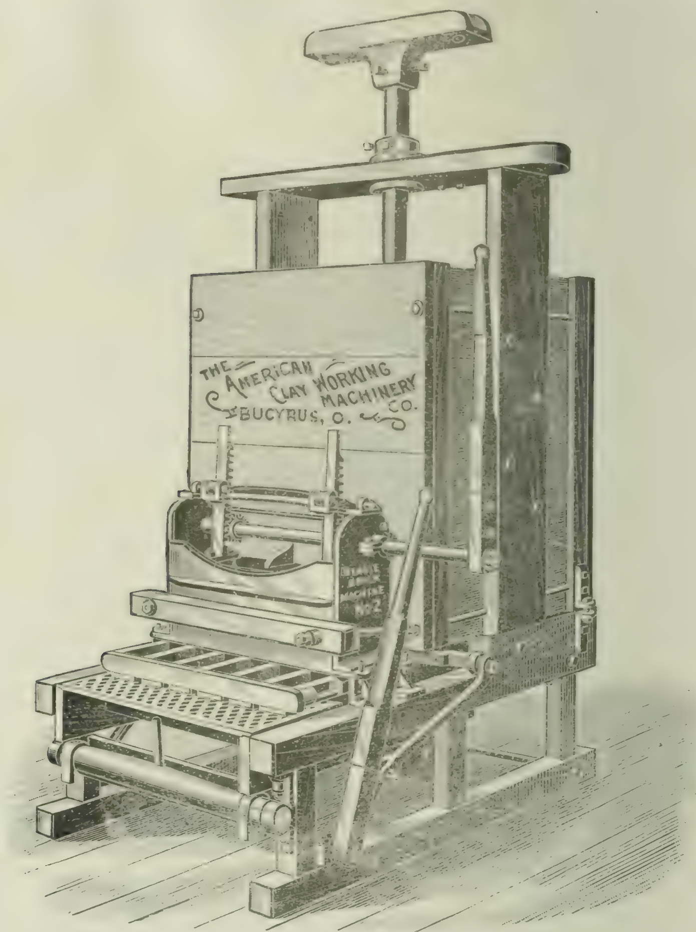
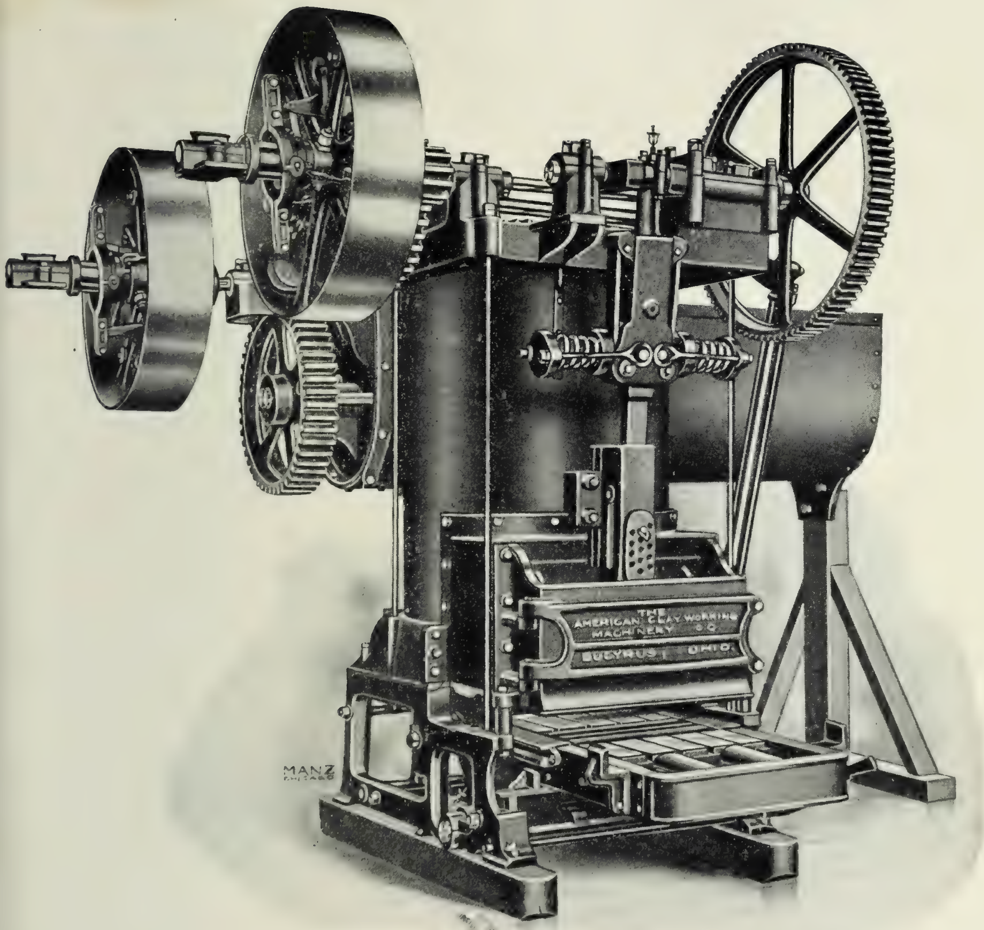


FIGURE 7. HORSE-POWER SOFT-MUD BRICK MACHINE.

process. A more plastic clay can be used to better advantage in a stiff-mud machine. It is possible in many clay pits to secure a variety of clays, so that mixtures may be made which will permit the use of all three methods of molding.

Plate XV.



SOFT-MUD BRICK MACHINE AND PUG MILL.

Soft-mud Process.

Hand Molding.—The tempered clay is taken from the soak pit or the ring pit and loaded on a wheelbarrow by the use of a spade. The wheelbarrow is then run to the molding table, which usually stands on the drying floor. The drying floor is a level and smooth tract of land which is covered with a thin coating of sand. The molding table is now sprinkled with water and then with sand, and the clay transferred from the wheelbarrow to the table. The off-bearer takes a molding frame which contains six molds, and dipping it first in water and then in sand, places it on the table in front of the molder. The molder takes a mass of clay, rolls it, and kneads it. He then drives it by a sudden downward stroke into a mold. This is repeated until the six molds are filled. The clay is stroked from the top of the mold by the use of a wire stretched between the points of a bow. The surplus clay cut from the top of the molds is called "caps," and is thrown back on the table to be used again.

The off-bearer takes the molding frames and empties them upon the drying floor. After drying for a few hours the bricks are turned upon edge, a process called edging. After remaining upon the drying floor from twelve to twenty-four hours the bricks are laid in loose piles, a process called "hacking." Hacking the output of the preceding day allows the use of the same drying floor for the new day's run. Then it makes it possible better to protect the brick from rain, because of the limited space which they now occupy. When they are piled up canvas or boards may be used to cover them.

In some yards the molding tables are moved along between racks in which the brick are placed upon pallets. As soon as the sections on each side of the table are filled with brick-loaded pallets the table is moved to the next section. One man can mold 8,000 bricks in a day of ten hours, but in most plants from 5,000 to 6,000 is considered a day's work. In one plant one man molds and places in the rack 6,000 bricks, for which he receives $1.50 per day.

Machine Molding.—According to the power used molding machines may be classed as horse-power machines and steam-power machines. The horse-power machine consists of an upright rectangular box in which a vertical shaft supplied with arms turns by means of a sweep. The sweep is attached to the shaft near the larger

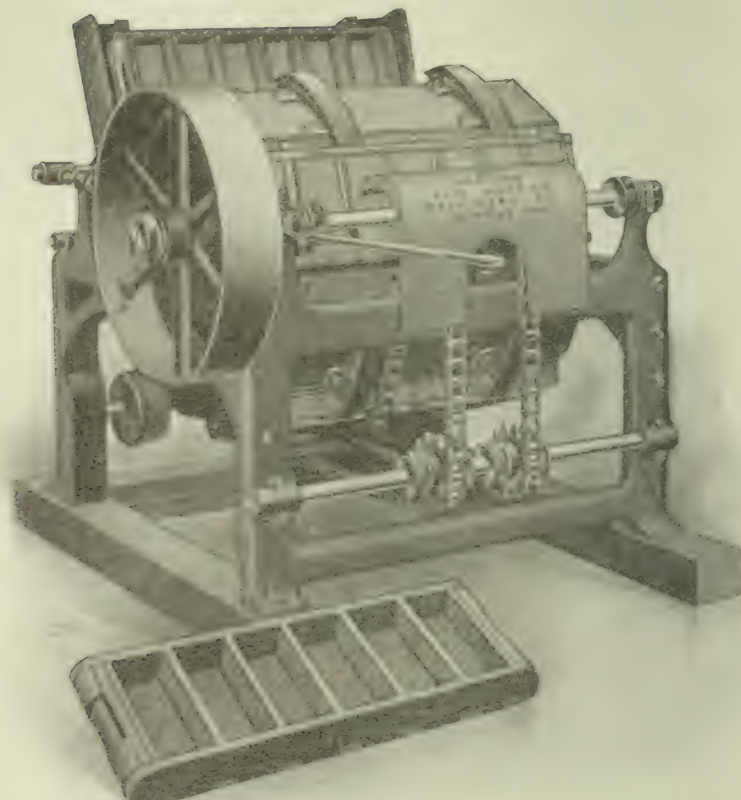


FIGURE 8. BRICK MOLD SANDING MACHINE.

end of the former, the projecting heavy end of the sweep being used as a counterpoise. The horses are hitched to the small end of the sweep and travel in a circular path around the machine.

The clay is thrown into the opening at the top of the machine, and after being thoroughly mixed or pugged by the arms in the upper part of the box, is worked to the bottom and pressed by plungers located near the bottom of the shaft into the molds. The molds are generally held in wooden frames, there being six molds to a frame. The molds are passed under the machine at one side, become filled fr m the press box and are taken out on the other. By moving a lever the filled frame is thrown out and an empty one inserted beneath the press box. They may not be completely stroked as they leave the machine, so that it may be necessary to use a wire or paddle to remove remaining clay. The molds are first dampened and then sanded. The use of the sand is to prevent the clay from sticking to the molds. The more plastic the clay the more tenaciously it clings to the molds. The molds may be sanded by shoveling sand into the molds, shaking it about and then tossing it out.

The mold-sander is a machine constructed for the purpose of saving labor in sanding molds. It consists of a frame which rotates in a cylinder. The molds are placed in the frame, and by the rotation of the latter the molds are forced through a bed of sand in the bottom of the cylinder.

Some of the soft-mud horse-power machines are placed upon low trucks and moved from soak pit to soak pit as the clay is used. Machines of the horse-power type have a capacity of from 8,000 to 15,000 bricks per day of ten hours. Soft-mud machines of steam power have a capacity ranging from 18,000 to 35,000 bricks per day. For a machine of the latter capacity five men and three boys are required at the machine. Three off-bearers are required if no car system is used; if a car system is used one off-bearer can handle the output of the machine.

Indurated clays and clays of high plasticity cannot be used with economy in the soft-mud process. In this State only the sandy type of surface clays is used. The residual clay covering the loess is molded in a large number of plants by the soft-mud process. The Selma residual is not generally successfully used in the soft-mud process unless there is considerable sandy clay present for mixing.

There are sometimes nearby deposits of Lafayette which may be used for tempering the clay. The alluvial clays of the Yazoo basin have been used for the manufacture of soft-mud brick. The sandy type of clays is best adapted to the soft-mud process. The "buckshot" clays adhere to the mold, shrink excessively and are difficult to pug.

Stiff-mud Process.

The machines used in the stiff-mud process of molding are of two types, a vertical machine, in which the clays are pressed into the molds by the action of plungers, and an auger machine, which may be either vertical or horizontal.

Plunger Type Machine.—The plunger machine is provided with a revolving wheel which contains the molds. As the wheel revolves clay is pressed into some of the molds by descending plungers, then as the plungers are lifted, the bottom of the mold rises and forces the molded brick out. Thus a portion of the wheel passes under the machine and a portion is in the open and forms the delivery table. The pugging chamber is usually directly above the molds. Just enough water is added to the clay to form a stiff mud. The molded brick are in a condition to permit handling without danger of much loss, whereas a soft-mud brick would first require a certain amount of drying.

Auger Type Machine.—In the vertical auger type machine the clay is forced by an auger to the base of the machine. From this point the clay is forced through a rectangular die. The size of this die may be either the same size as the cross section of a brick or the same size as a horizontal section, The clay which is forced through the die forms a bar of clay which is usually strong enough to retain its shape under considerable strain. After the clay is tempered it is placed in the small pugging chamber in which there turns a vertical shaft. At the top this shaft is provided with small blades for pugging the clay. The lower part of the shaft is provided with an auger, which catches the clay forced downward by the pugging blades, and presses it through the die. The friction of the bar of clay against the die may cause the edges of the bar to break and curl, forming serrations. The clay may lack cohesive power, in which case more bonding material should be added.

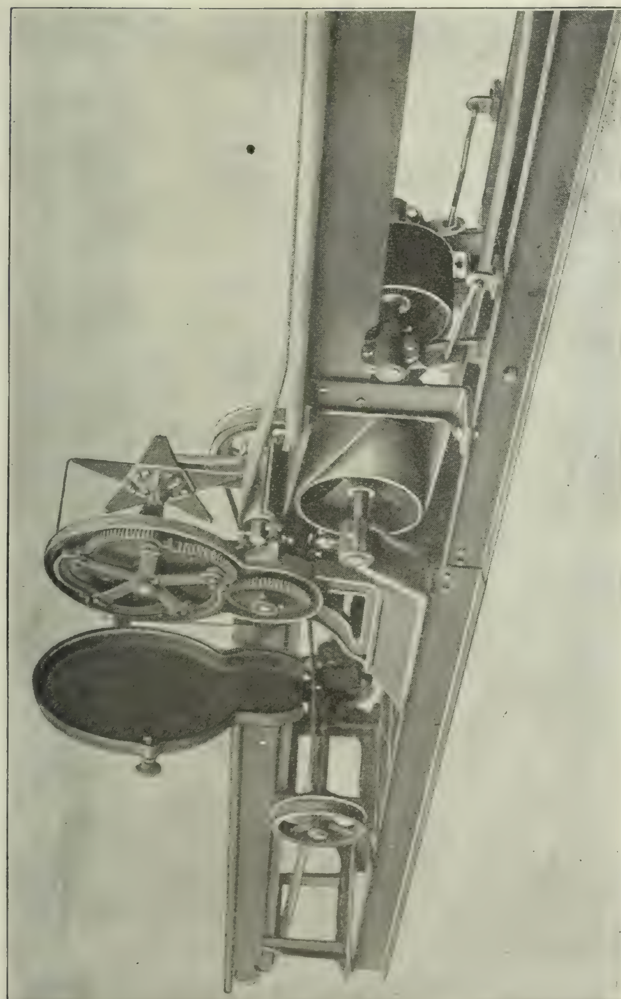


FIGURE 9. AUTOMATIC CONTINUOUS ROTARY BRICK CUTTER.

Various substances are employed to decrease the amount of friction between the steel die and the clay bar. Steam under high pressure may be forced in around the bar in the die. Kerosene or lubricating oil is often employed as a lubricant in some plants and soap suds in others. The surface of the bar is sometimes coated with sand as it leaves the die, to facilitate handling and hacking without injury.

The spiral motion of the auger, the friction of the clay against the surface of the auger, producing smooth clay surfaces, and the differential velocities in the bar of clay produced by friction of the die, all cause laminations in the clay.

In the horizontal auger type of stiff-mud machine a horizontal shaft works in a cylindrical pugging chamber, and supports at the end opposite the die short blades which pug the clay and force it to the auger, by which it is in turn forced through the die.

In the multiple-bar type there are two or more dies through which the clay is forced, thus forming as many parallel bars of clay.

As the clay issues from the die it is carried by a belt across the cutting table, where it is cut into bricks. The cutters are either "side-cut" or "end-cut." Where the side-cut is employed the width of the bar is the length of the brick, and where the end-cut is employed the width of the bar is the width of the brick.

The cut surface of the brick in the former is on the side of the brick, in the latter on the end of the brick. Side-cut brick dry more rapidly than end-cut brick, because of the greater area of cut surface which is more porous than the die-puddled surface.

Some cutters are operated by hand, others are automatic. There are two automatic side cutters in general use. One is the rotary, consisting of a wheel provided with wire spokes. By the rotation of the wheel these wires are passed through the bar of clay at regular intervals, the movement of the bar being co-ordinated with the rotation of the wheel. The other side cutter is the oscillating, reciprocal cutter, which consists of a frame between the projecting points of which wires are stretched. The wires are separated by the thickness of a brick. These wires, by a lateral or downward movement, are forced through the bar. During the time of cutting the bar is moving forward and the cutter has a reciprocal movement.

The end cutter consists of a revolving wheel, the spokes of which are bifurcate near the ends, having wires stretched between the points of the bifurcations. As the wheel revolves the wires are forced through the bar of clay cutting it into brick lengths.

As the bricks leave the cutter they are caught by the off-bearing belt, which moves at a greater velocity than the bar of clay, and soon separates the brick. The brick are taken from the off-bearing belt and placed upon cars or pallets for transportation to the dryer.

Repressing Brick.

Stiff-mud brick or soft-mud brick after molding are often pressed in a machine called the "repress." The repress consists of a steel mold box into which the brick are placed and subjected to strong pressure. The hand repress (see Fig. 10) consists of a heavy iron frame supporting a steel mold box, which is provided with a removable top and a movable bottom plate, which is forced upward against the brick in the mold. The pressure exerted by the movable bottom (plunger) is obtained by throwing back the lever. When the top is removed and the lever thrown back, the repressed brick is forced to the top of the mold. These represses have a weight of from 700 to 900 pounds and a capacity of from 2,000 to 3,000 brick per day.

The larger represses are operated by steam (see Plate XVIII). They generally have two molds and have a capacity of from 10,000 to 25,000 brick per day. They vary in weight from 5,000 to 9,000 pounds and exert a pressure of 4,000 or 5,000 pounds per square inch. The pressure may be applied by plungers from above or by plungers both above and below.

The brick from a stiff-mud machine may be taken immediately to the repress. Soft-mud brick must dry to about the consistency of stiff-mud brick before repressing. There is an advantage to be gained in allowing stiff-mud brick to dry a little before repressing, as in that case defects of drying may be partly obliterated.

The principal things to be gained by repressing are: (1) An increase in the density of the brick. The clay particles are brought closer together and their union is more perfect. This diminishes the porosity of the brick and decreases its absorption power. (2) A partial destruction of laminations and serrations. Stiff-mud brick

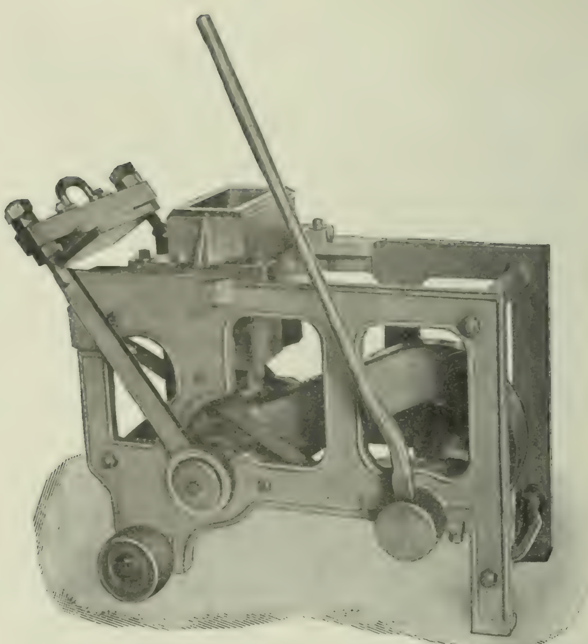


FIGURE 10. HAND-POWER REPRESS BRICK MACHINE.

are often serrated on the edges. The auger also produces a laminated structure. Both of these structures may be at least partly obliterated by repressing. (3) The surfaces of wire cut brick are often rough. This roughness may be destroyed and the surface of the brick made smooth by repressing. (4) The form of the brick may be improved by repressing and its strength increased. The edges of the brick which may have been rounded in the die are shaped. Indentations are removed. (5) Any desired name, design or mark may be imprinted on the surface of the brick.

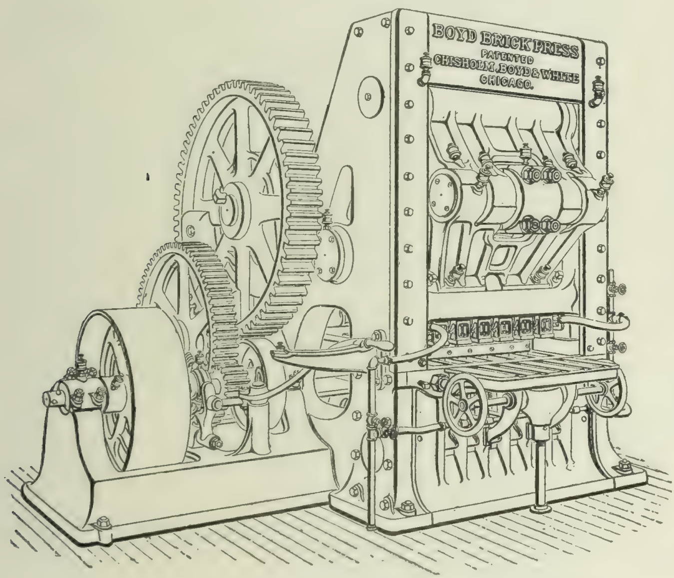


FIGURE 11. SIX-MOLD DRY-PRESS BRICK MACHINE.

Dry-press Process.

In the dry-press process the clay is first reduced to a powder in a disintegrator or pulverizer. It is then screened to remove all particles larger than one-sixteenth of an inch in diameter. The air-dried clay is then pressed into molds with a pressure sufficient to cause the particles to adhere so firmly that the brick may undergo without crumbling all of the handling that raw clay brick usually have to endure. The dry-press machine (see Figure 11) consists of a heavy steel frame containing a press box and a delivery table. The molds

(usually four to six) are filled with clay by a charger which is connected with the clay hopper by a canvas tube. When filled with clay the charger glides forward over the molds, filling them with clay. Then as the charger returns to be refilled the plunger descends and forces the clay into the mold. At the same time the bottom of the molds are pressed upward and thus the clay is subjected to two pressure movements. As the plunger rises the bottom of the molds continues to come up, thus forcing the brick out of the molds to a level with the surface of the delivery table upon which they are pushed by the next forward movement of the charger. The surfaces of the molds are heated by steam in order to prevent the clay from sticking. To prevent the imprisonment of air in the brick, holes are made in the press plates to allow its escape.

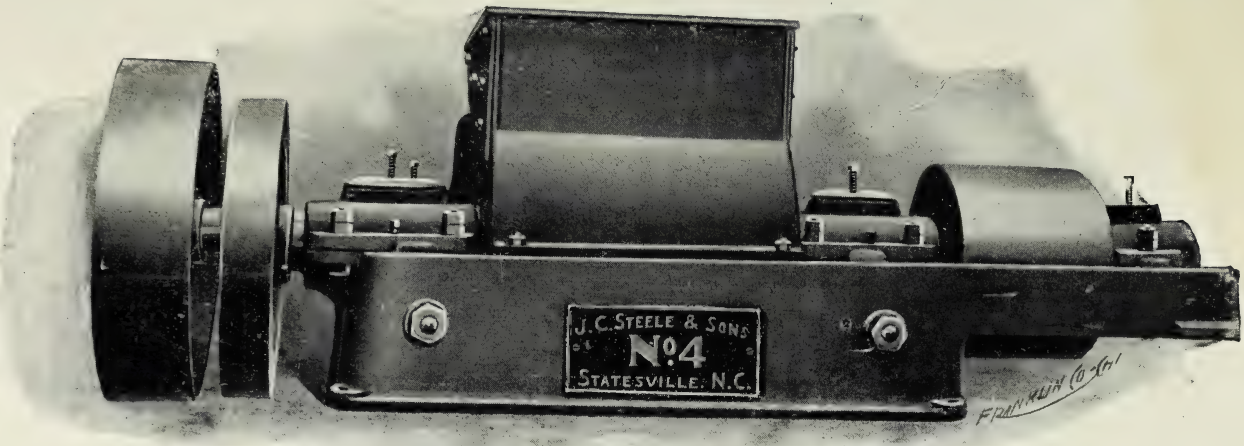
The clay used by the dry-press machine is generally placed in a storage shed and allowed to mellow for a few weeks, or in some plants months before it is used. Under the mellowing process capillary moisture becomes more thoroughly distributed, the clay lumps are softened and the reduction to the powdered state rendered easier. In case two or more kinds of clay are used, the mixing may be done thoroughly by placing them in the storing shed in successive layers. In using the clay a vertical section of the deposit is taken. Storing a large quantity of clay in the shed during favorable weather makes it possible for the plant to continue operations during unfavorable weather periods. The dry pressed brick may be taken directly from the press and placed in the kiln. The expense of drying is avoided. Because, however, of the density of the brick the water-smoking period is longer than in the soft-mud or the stiff-mud brick.

TABLE 17.

METHODS OF MOLDING MISSISSIPPI BRICK.

1. By soft mud process.	
a. Number of plants using hand power	11
b. " " " " horse power	2
c. " " " " steam power	7
2. By stiff mud process.	
a. Auger type, end cut, single die	19
b. " " " " double die	2
c. " " side cut, single die	6
d. Plunger, vertical type	7
3. By dry-press process	11
Total	65

Plate XVI.



CLAY DISINTEGRATOR.

DRYING.

When brick are brought from the molding machine they contain the water necessary for tempering the clay. Before they can be burned this water must be removed. It must be removed so gradually as not to impair the strength or appearance of the brick. This process of water removal is called drying. In the following pages are presented some of the fundamental facts upon which the removal of water from clay is dependent.

Principles of Drying.

Humidity is the condition of the atmosphere with respect to its water-vapor content. The total amount of moisture that the air is capable of containing at any given temperature constitutes the capacity of the air at that temperature. The capacity of the air varies with the temperature. The air is said to be saturated when the amount of water vapor which it contains is equal to its capacity. The amount of moisture actually present in the atmosphere is termed its absolute humidity. The relative humidity is the ratio of the absolute humidity to the capacity of the atmosphere. For example, air at a temperature of 50° F. has a capacity of 4 grains per cubic foot. Suppose, however, the air at this temperature contained but 2 grains of moisture per cubic foot. The absolute humidity of the air is 2 grains per cubic foot and its relative humidity is the ratio which 2 grains (absolute humidity) bears to 4 grains (capacity), which is one-half or 50 per cent. Air which has a relative humidity as high as 80 per cent is considered moist air. If the relative humidity is below 50 per cent the air is called dry air, and its humidity is low.

The capacity of the air depends upon its temperature. The higher the temperature of the air the more moisture it can contain. Air at a low temperature might be considered damp though it contains just the same amount of moisture as air which, at a higher temperature, would be considered dry.

For example, air at 50° F. has a capacity of 4 grains per cubic foot. Now, if the air at that temperature contained 3 grains per cubic foot it would be considered moist air, since its relative humidity is 75 per cent. Now let the same air be raised to a temperature of 100° F., and it now has the capacity of approximately 20 grains.

But the relative humidity is now only 15 per cent, and it is an exceedingly dry air.

Water is lost from a wet body by evaporation. Evaporation is the transfer of moisture from one area to a less humid area. Such transference does not take place between two saturated bodies, but between a saturated body and a non-saturated body. Water may pass from a wet surface to the surrounding air, provided the air is not saturated. Evaporation is produced through the vibration of molecules, which causes some of those at the surface to fly off into space. The vibration of the molecules is produced by heat, and the higher the temperature of the water the more rapidly the molecules separate. Evaporation takes place from the surface of ice, but it takes place much more rapidly from the surface of water at the boiling point. At this point the vapor tension is equal to the pressure of the atmosphere which it will displace.

At the point of evaporation water assumes the form of a gas, and expands to 1,700 times its liquid volume. When the surrounding air contains all of the vapor it can hold it is saturated. The point of saturation depends on the temperature of the vapor.

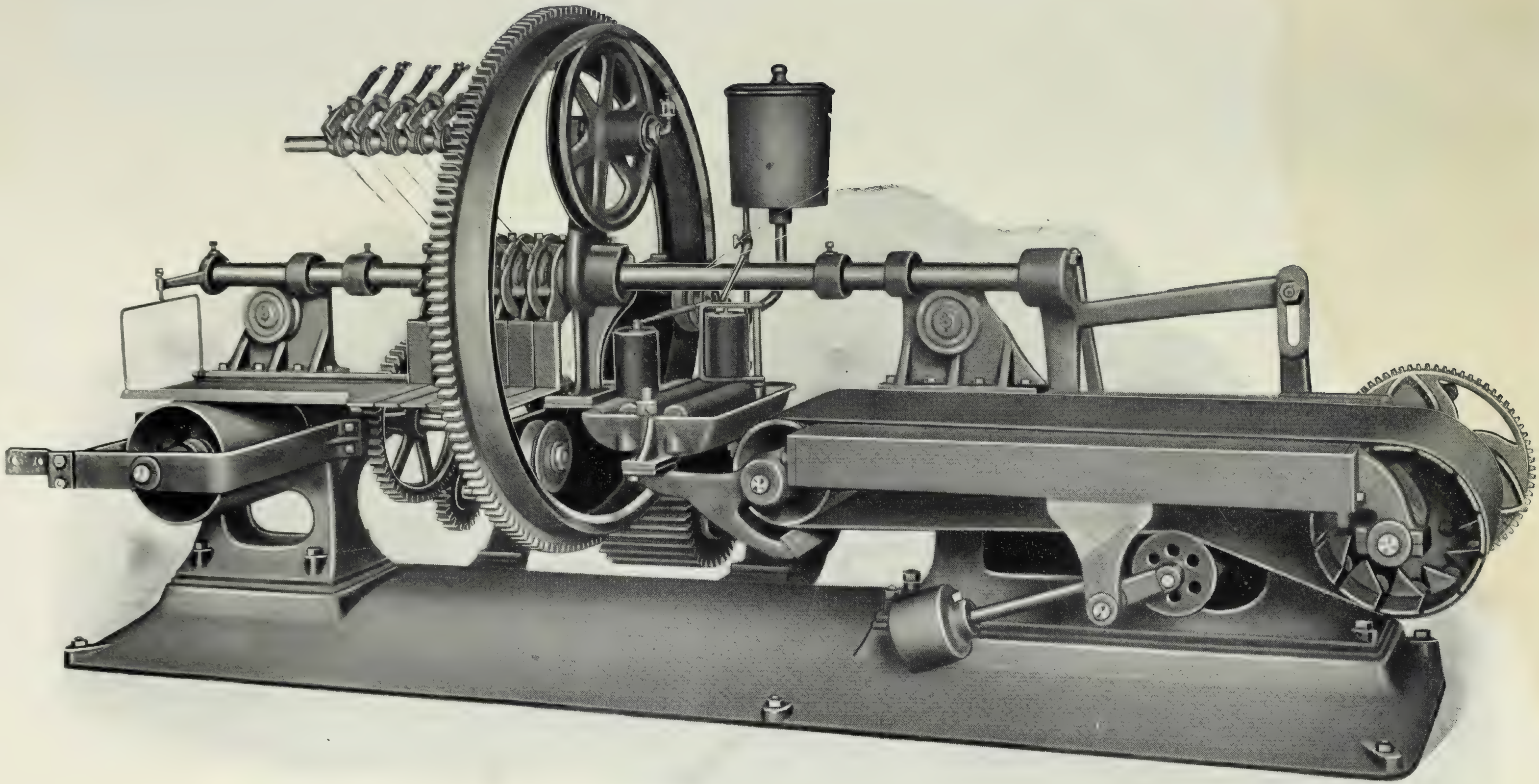
TABLE 18.

NUMBER OF GRAINS OF SATURATED WATER VAPOR IN A CUBIC FOOT AT VARIOUS TEMPERATURES.

10°	.776	34°	2.279	58°	5.370	82°	11.626
12°	.856	36°	2.457	60°	5.745	84°	12.356
14°	.941	38°	2.646	62°	6.142	86°	13.127
16°	1.032	40°	2.849	64°	6.563	88°	13.937
18°	1.128	42°	3.064	66°	7.009	90°	14.790
20°	1.235	44°	3.294	68°	7.480	92°	15.689
22°	1.355	46°	3.539	70°	7.980	94°	16.634
24°	1.483	48°	3.800	72°	8.508	96°	17.626
26°	1.623	50°	4.076	74°	9.066	98°	18.671
28°	1.773	52°	4.372	76°	9.655	100°	19.766
30°	1.935	54°	4.685	78°	10.277	102°	20.917
32°	2.113	56°	5.016	80°	10.934	104°	22.125

Water evaporates more rapidly into a vacuum than into space filled with air, but at a given temperature the same quantity of water will evaporate into each. A mixture of air and water vapor has a greater expansive power than air alone. If to a cubic foot of dry air weighing 516 grains at a temperature of 80° F., 11 grains of water vapor be added by evaporation, the whole mixture will weigh but 510 grains. Then its density is less than the original air.

PLATE XVII.



ROTARY AUTOMATIC BRICK CUTTER.

Brick are dried by evaporation of water which they contain. When taken from the mold, brick contains water in two forms, viz., the water which has been added for tempering, and hygroscopic moisture. The former passes readily from the clay at ordinary temperature; the latter can only be expelled at the temperature of boiling water. It is the water which is absorbed from the atmosphere, and is present in all clays except those kept in absolutely dry air, and is the water which is removed from brick in the process of water-smoking.

The object to be obtained in drying brick is the economical and rapid removal of water without impairing in any way the quality of the brick. The tenacity with which moisture is held by clays varies. As a rule the finer the grain of the clay constituents, the more slowly it gives up its water. Since clay is as a rule finer in grain than sand, the higher the amount of clay the greater the difficulty of drying. Since plasticity is affected by these conditions, the higher the degree of plasticity the more difficulty encountered in drying. A very sandy clay will dry rapidly, but it may be weak because of the small amount of bonding material. When the brick are taken from the machine, they have the same temperature as the surrounding atmosphere. If they are put in a dryer which has a higher temperature, they begin to lose moisture rapidly as the temperature of the dryer is raised. But since clay absorbes heat slowly, if the temperature of the dryer is too high, the outside of the brick may become dry before the inside becomes hot. This produces differential shrinkage, the outside of the brick contracting more than the inside. The results of such differential contraction is the cracking or checking of the brick. The more plastic the clay, the more care must be exercised in drying. The remedy lies in the very gradual increase in the temperature of the brick.

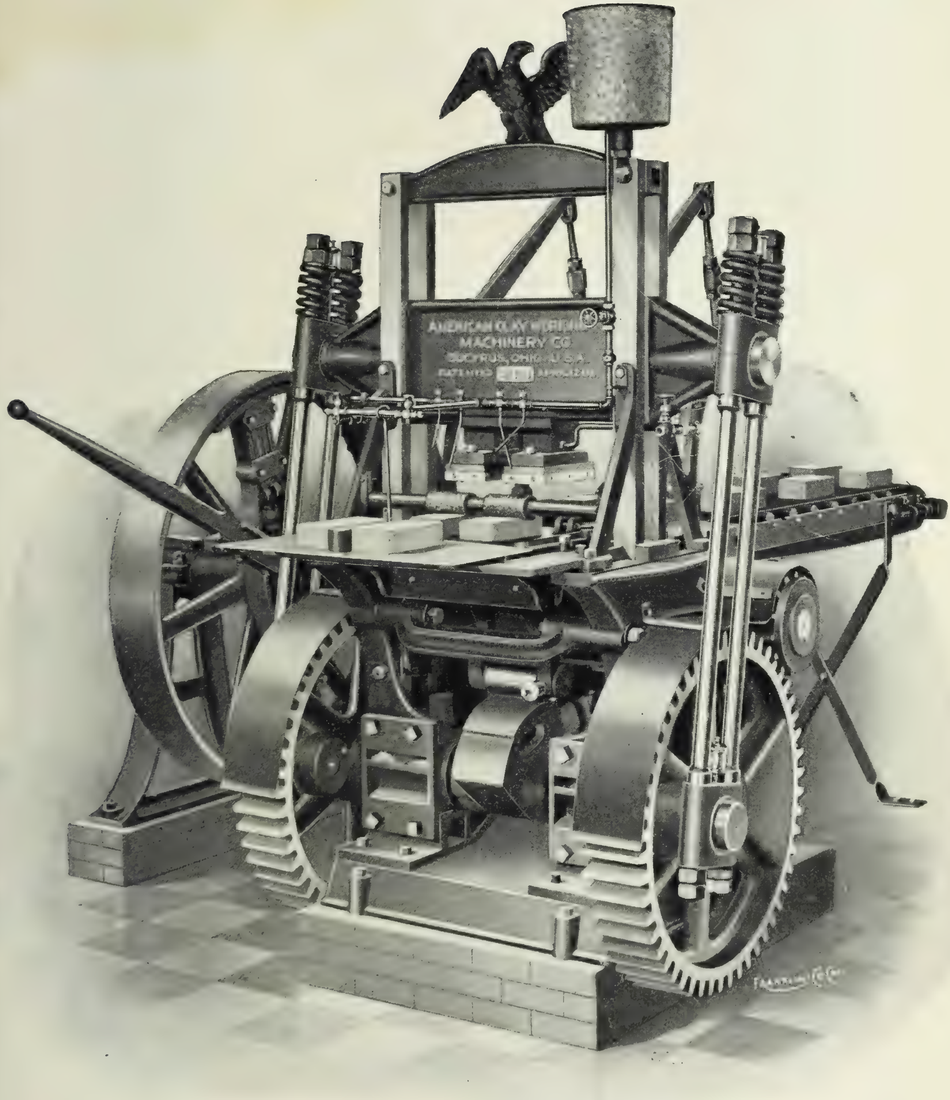
In many of the steam dryers now in use, a "dead chamber" is used for heating the brick to the temperature of the first chamber of the dryer. The "dead chamber" is a closed division of the dryer into which steam is turned, there being no means of circulation, or at least very little. The brick do not dry, but become heated thoroughly by the steam. When they reach the temperature of the air at the beginning of the dryer, they are run into the first chamber of the dryer, and are then in a condition to pass through the dryer rapidly.

Since air is the medium through which the water is removed from brick, the drier the air used the greater its drying capacity. The air used in an artificial dryer must be taken from the atmosphere, therefore, the amount of moisture that enters a dryer on a given day will depend on the humidity of the atmosphere. Beyer and Williams* make a calculation of the amount of heat necessary to evaporate the water contained in 1,000 brick. The subject is treated as follows: "Clays vary a great deal in the quantity of water required for tempering. Since tempering water only is removed in the dryer, the amount which it is necessary to evaporate in drying also varies. As an average, it may be said that clays worked by the plastic process contain 22 per cent of water. For one thousand brick, this means in the neighborhood of 1,700 pounds of water to evaporate in drying. A dryer tunnel containing twelve cars each loaded with five hundred standard bricks must pass enough air to carry out over five tons of water from these brick. It thus becomes a problem for investigation to determine for a given dryer the most saving conditions under which this water can be removed.

"In open air drying, the currents of air which carry away the water are warmed by the sun's heat. The specific heat of air is .2374. A cubic meter (1.308 cu. yds.) of air weighs 1.293 kilograms at O°C. and 760 mm. barometric pressure. The heat contents of each cubic meter of air at zero degrees is, therefore, 1.293 times .237 = .306 kilogram calories. At any higher degree, its contained heat would be, $\frac{1.293 \text{ times } .237 \text{ times } t}{1 + a t}$, in which a is the coefficient of expansion = .00367 and t the observed temperature. If we assume an average summer heat of 16 C. (most out of door drying being done in the summer), it is seen by the formula that the heat content of a cubic meter of air is 4.631 units, which shows an average of essentially .3 heat units for each degree of temperature. These heat units are taken up as latent heat by the water in drying and as a consequence the temperature of the air is lowered. This means that for every degree the air is cooled, it loses .3 of a unit of heat. The measurable heat of water and the latent heat of water vapor formed at ordinary temperatures may be taken as 611 heat units, *i. e.*, to evaporate one kilogram of water at 16 C. requires 611 heat units; .3 units, therefore, $\left(\frac{.3 \text{ times } 1{,}000 \text{ gms.}}{611}\right)$ will evaporate at this temperature only .491 of a gram.

*Iowa Survey, Pages 239–243, Rept. for 1903.

PLATE XVIII.



STEAM-POWER DOUBLE-MOLD BRICK REPRESS.

"We have already assumed an average of 1,700 pounds (772+ kgms.) of water per thousand brick. To evaporate 772 kilograms of water requires 611 times 772=471,692 heat units. To dry a thousand brick, therefore, with air at ordinary temperature, requires that 1,572,301 (772,000÷.491) cubic meters of air lower one degree in temperature to furnish the required amount of energy. Or, where the air is somewhat confined as in drying sheds so that it may remain in contact with the wet ware for some time, the same evaporative power would be possessed by one-half the volume lowering two degrees, or by one-tenth lowering ten degrees and so on.

"Whether or not drying actually approaches in efficiency these theoretical figures depends largely on the humidity of the air. Air near its saturation point gives up its heat much less readily and will consequently take up water more slowly than comparatively dry air. Rapidity of movement of the currents of air also influence their drying capacity. As a general thing, very little change of temperature is ever actually noticed in outside drying, but the drying depends largely on the air circulation. The more rapidly this takes place, the more air is brought in contact with the clay and consequently drying progresses more speedily.

"In closed chamber dryers the conditions are different from those discussed in several particulars. The air no longer circulates of itself but a draft must be produced to move it. The heat for drying is not contained in the air as it enters from the outside, but must be supplied to it artificially. Both movement of the air and heating it requires the expenditure of energy which is not necessary in out of door drying. Of the heat supplied to the air, it is clear that not all is utilized in the evaporation of water; for this air leaves the dryer at a higher temperature than it enters, thus carrying out considerable quantities of sensible heat. Likewise, the brick enter the dryer at atmospheric temperatures and leave it at much higher temperatures. These are the chief sources of waste of heat in the dryer and are in turn briefly treated.

"On leaving a drying chamber, one cubic meter of vapor-saturated air at 30° C. consists of .958 cubic meter of dry air and .042 of water vapor $\left(\frac{760-31.6}{760}\right)$, where 31.6 is the tension of aqueous vapor.

"The .958 cubic meter of dry air can hold the following heat units: $\frac{1.293 \times .958 \times .237 \times 30}{1+.00367 \times 30} = 7.935$ heat units.

"When this same dry air entered the dryer at, say, 10° C., it had a volume of

$$\frac{958}{1+.00367\,(30-10)} = .893 \text{ cubic meters.}$$

"This volume of air could carry as it came into the dryer

$$\frac{1.293\times.893\times.237\times10^\circ}{1+.00367\times10} = 2.639 \text{ heat units.}$$

"The amount of heat taken out of the dryer, therefore, in each cubic meter of air under the assumed conditions is 7.935—2.639 =5.296 heat units.

"The above result is obtained on the assumption that the air on issuing from the dryer is completely saturated. This is seldom if ever true. Its degree of saturation or relative humidity may be ascertained in any instance and the value used in the formula. Assuming for example that the outgoing air is but half saturated, which is ordinarily more nearly the case, similar calculations to the above will show that at 30° C. 8,108 heat units will be carried out per cubic meter of saturated air. At 10° the same air carries in 2.696, making a loss in this case of 5.412 heat units. If each cubic meter passing through the dryer causes a loss of 5.412 units of heat, the total loss per each thousand brick is 56,610 heat units.

"In the same manner may be calculated the loss of heat incurred by bringing the air into, and removing it from, the dryer at any observed temperatures.

"We have seen that at these low temperatures 611 heat units are required for the evaporation of each kilogram of water. As has been shown, to remove the water from 1,000 brick (772 kgms.) requires 471,692 heat units. And since each cubic meter of air at the highest temperature, 30° C., can evaporate 13.55 grams of water, to dry 1,000 brick takes 772×13.55 or 10,460+cubic meters of air.

"Seger gives the following formulae for the calculation of the capacity of chimneys. In their practical application these expressions may be used for determining the dimensions of a stack for circulating an amount of air, at the temperatures of operation, which is found necessary to remove the water from a given amount of clay in the time required to dry it.

"$V = 628\sqrt{\frac{(t-t^1)\,dh}{4.08.+016h}}$ = velocity of air in meters per minute and,

"$V = \frac{3.1416d^2v}{4}$ = volume of air in cubic meters per minute.

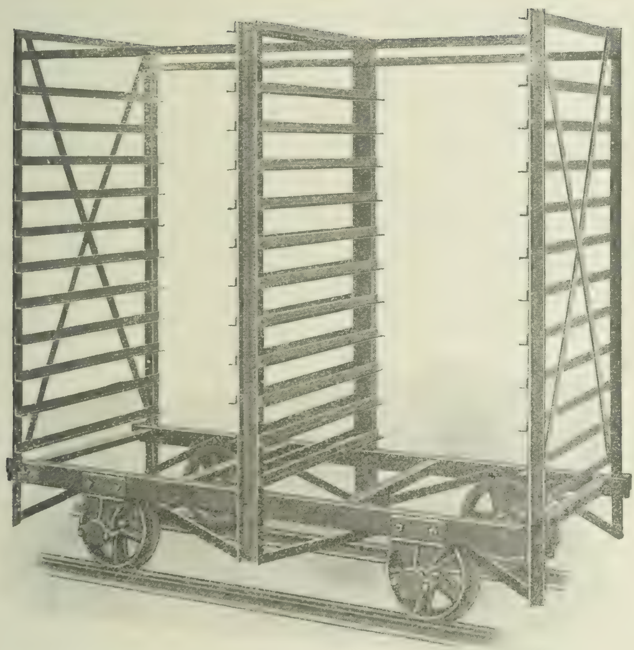


FIGURE 12. STEEL RACK CAR FOR TRANSPORTING BRICK ON PALLETS.

"In these formulae:

"$t-t^1$ = the temperature difference between the shaft of the chimney and the outside air,

"d = the diameter of the chimney at its mouth,

"h = the height.

"The clay as it enters the drying chamber has the temperature of the atmosphere and as it leaves carries out considerable quantities of sensible heat. The specific heat of clay is about .2. The heat carried out is calculated by the weight of the ware, or, M, multiplied by .2 $(t-t^1)$ where $t-t^1$ = difference in temperature of the brick at entrance and exit. One thousand brick contain on an average 7,700 pounds, 3,500 kilograms, of dry clay. Under the conditions assumed above, $3{,}500 \times .2\ (30-10)$ 14,000 heat units per thousand brick.

"We have now obtained the amount of heat used in the evaporation of water from 1,000 brick, 471,692 heat units; that taken out as sensible heat in the escaping half-saturated air, 56,110, and the heat dissipated by the clay itself, 14,000 heat units. Total energy necessary to dry 1,000 brick, neglecting radiation, is, therefore, 542,302 units of heat.

"This energy is supplied in artificial dryers by the combustion of fuel. The average Iowa coal furnishes 6,700 heat units per kilogram. To dry a thousand brick requires the consumption, therefore, of, in round numbers, 81 kilograms, or 178 pounds of coal.

"By carrying out similar calculations to the above for a range of temperatures and different degrees of humidity, it may be shown that (1) economy can never be obtained unless the air is removed very nearly saturated. The rule in this regard is, therefore, to remove the air only after it has taken up practically all the water vapor it can hold, and before dew is deposited. (2) Economical drying in closed compartments can be had only at temperatures above 50° C. (122° F.), and below 100° C. (212° F.), when the air is removed as nearly saturated as possible. The amount of heat carried out by the air rises rapidly as the humidity decreases; and as the temperature of drying is lowered the ratio of heat loss to that actually used in the evaporation of water increases rapidly."

Methods of Drying Brick.

Brick dryers may be classed as open air dryers, and artificial dryers. The former may be further subdivided into (*a*) open yard dryers, (*b*) rack and pallet dryers, and (*c*) shed and hack dryers. The latter may be classed as (*a*) hot floor dryers, (*b*) chamber dryers, and (*c*) continuous tunnel dryers.

Open Yard Dryer.—This system of drying is used in soft-mud plants. The brick are placed on pallets from the mold. The loaded pallets are taken by the off-bearer to a sanded, open yard where they are emptied by inverting them. After drying a little, the brick are placed on edge to allow both sides of the brick to dry equally, and to prevent cracking of the upper surface due to unequal drying. After drying from 12 to 24 hours, the brick are hacked on the yard until the air drying is complete. The hacking makes it possible to handle a larger number of brick per yard, and at the same time makes it possible to more easily protect the brick in case of rain. The principal objections to this system of drying arise from the great amount of labor required to handle the brick, and the high per cent of loss sustained in inclement weather. The source of energy for the evaporation of the water is from the sun. There is no means of controlling the form of energy in the open yard. And it is impossible to control the circulation of the air and thus check the removal of moisture.

Rack and Pallet Dryer.—This system is used for both soft-mud and stiff-mud brick. The racks are covered with A-shaped roofs and generally open at the sides and the ends. Some, however, are provided with temporary walls consisting of movable plank, canvas, or burlap. Soft-mud brick are placed on pallets. Each pallet holds one mold full of brick, usually six. Where the brick are molded by hand, it is the practice to move the molding table along between the racks, filling them section by section.

Where a machine is used for molding, the brick are carried by hand, wheelbarrow or car to the racks. In some yards a rack car is used, and the loaded pallets are transferred from the car to the racks by an elevating movement of the car.

Usually in stiff-mud plants, the brick are packed upon large pallets as they are taken from the table. The pallets contain from

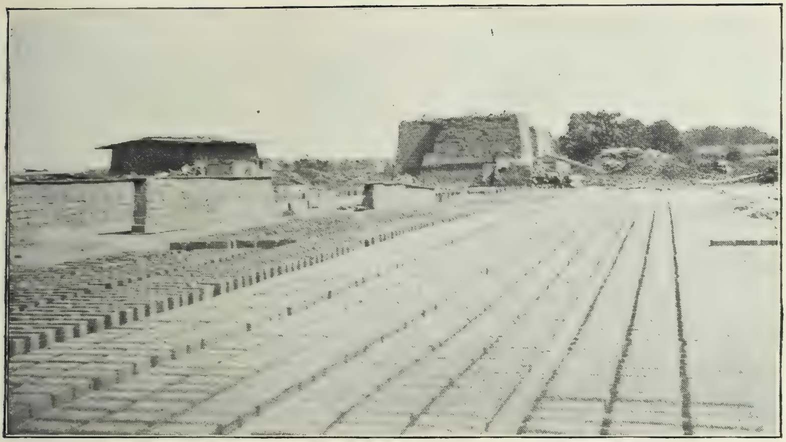
200 to 500 bricks. These pallets are transferred by elevating cars to racks or to sheds as the case may be. Considerable loss may be experienced in case no protection is provided for the racks in the way of side walls. Dashing rains may beat upon the brick. Currents of air may cause cracks by too rapid extraction of moisture from the exposed sides of the brick. The length of time required for drying is dependent on the conditions of the weather. In a dry atmosphere the brick may dry in a few days, whereas under humid conditions it may require weeks.

Shed Dryer.—Some plants are provided with large sheds with low supports or racks made in rows with car tracks between for the purpose of receiving the pallets with the hacked brick. In others no supports are used; the pallets are placed upon the floor or the brick hacked upon the floor without pallets. The brick are criss-crossed so that there is free circulation of air between them. The percentage of outside exposed brick is less than in the use of the rack and pallet and consequently the per cent of loss is less. The protection from storms is more efficient in the use of sheds. The cost of construction, however, is somewhat higher for the sheds. As in the case of the open yard, the source of energy for evaporation is from the sun for these last two mentioned dryers. The air currents, however, can be controlled. There is not the necessity of economizing in the volume of air that becomes imperative in the use of the steam or hot air dryer.

Artificial Dryers.—There are numerous forms of dryers which utilize either directly or indirectly heat derived from the combustion of fuel. Some of these dryers consist of a brick or metal floor under which fires are built. The clay ware to be dried is placed on the heated floor. In other floor dryers the floors consist of wooden strips which are heated by means of steam coils placed beneath the floor. This last form of dryer is commonly used for drying sewer pipe, drain tile, hollow blocks and terra cotta.

For drying brick two types of artificial dryers are in common use, the chamber dryer and the continuous tunnel dryer. The former consists of one or more rooms or chambers into which the brick are placed. Commonly the brick are hacked upon cars and the cars run into the dryer. The heat is furnished from steam pipes

PLATE XIX.



A. OPEN YARD SYSTEM OF DRYING, HOLLY SPRINGS.

B. HAND MOLDING AND STARTING A SCOVE KILN, HOLLY SPRINGS.

laid beneath the track. In some dryers pipes are also placed along the side walls or even along the roof. Under the track is considered the most advantageous position for the pipes. As the air in the chamber becomes heated it expands, rises and takes up moisture from the moist brick. The moist air is taken out through one or more chimneys or through a large wooden stack. The air is conducted from chamber to chamber by means of flues.

In the continuous tunnel dryer the heat supplied is increased as the distance from the entrance to the tunnel increases. The increase in heat may be obtained by increasing the number of sections of steam pipe. The brick are placed upon cars, which are run into the dryer from the stack end of the tunnel. They are gradually forced through the tunnel in the direction of increasing heat and decreasing moisture. The dried brick are taken out of the tunnel at the end opposite the stack.

Hot air used in drying brick may be obtained by utilizing the waste air in burning pottery or by heat produced in the burning of fuel. The air heated directly by the combustion of fuel is forced through the tunnel by means of a fan placed at the end opposite the dryer. The air heated by the furnace is drawn into a chamber where it loses its soot. After passing to the fan it is forced to the mixing chamber to be mixed with cold air. From the mixing chamber it is conducted to the dryer.

BURNING.

Burning is a term which is applied to that part of the process of brick manufacture during which the raw clay product is subjected to high temperatures. These high temperatures bake the clay. Hence the burning of brick is not at all analogous to the burning of wood or coal. The clay is not consumed but its moisture is expelled, its density and hardness are increased, and its plasticity destroyed. The changes which take place are partly chemical and partly physical.

Brick are first hardened by drying in the sun. The use of sun-dried brick dates back probably to 8000 B. C. Such brick are still used for building purposes in some arid or semi-arid regions. Burned brick were first used about 4500 B. C.

The process of burning consists of two periods, the water-smoking period and the burning period. The object of water-smoking is to

evaporate the water in the clay, and for this purpose the temperature of the kiln is maintained at about 212° F. The production of too high a temperature may result in cracked brick from stresses set up by steam. The air which enters the bottom of the kiln soon becomes laden with moisture. Unless this moisture is removed, it may be condensed in some cooler portion of the kiln. The water thus formed upon the surface of the brick may soften them or produce kiln white. The moisture-laden air should be removed as rapidly as possible. At the beginning of the water-smoking period, a large amount of air should be allowed to enter the kiln, and be maintained until the ware is dry. As the temperature of the kiln increases, the amount of air may be gradually diminished. Wood is generally used for water-smoking, and it should be dry. The firing should be so conducted as to produce a slow fire and little flame. Hard wood and coke are said to give the best results.

During the burning process, the temperature should be increased slowly until the temperature has reached 932° F. to 1,112° F., at which temperature the water of crystallization is driven off. After that, the temperature may be increased more rapidly until the point of incipient fusion is reached. The temperature may then be maintained until the heat has reached the center of the ware. Care must be exercised at this stage of the process, because in some clays the difference between incipient fusion and viscosity may not be very great.

In some parts of France, Belgium and England, brick are burned in the open by mixing the fuel and the raw brick. However, in most plants, the brick are burned in kilns.

Types of Kilns.

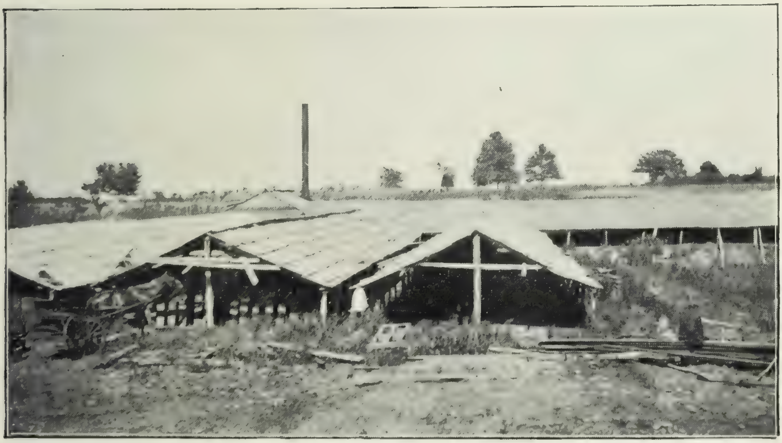
Brick kilns may be classed according to the following outline:

Up-draft kilns.
- A. Scove kiln.
- B. Dutch or clamp kiln.

Down-draft kilns.
- A. Beehive kiln.
- B. Rectangular kiln.
- C. Continuous kiln.

PLATE XX.

A. SETTING BRICK IN A SCOVE KILN, STARKVILLE.



B. SHED DRYER, BRICK HACKED ON GROUND.

UP-DRAFT KILNS.

In the up-draft kilns, the heat passes through the brick in the kiln from the bottom toward the top. In the down-draft kilns, the heat is conducted through flues to the top of the kiln and from there it passes downward through the brick and is withdrawn through flues at the bottom of the kiln connected with stacks.

Scove kiln.—The scove kiln is the simplest type of kiln and because of its cheapness is much used in small plants. The brick are set in a rectangular mass and surrounded by a double wall of soft-burned brick. The outer surface of the wall is coated with mud in order to prevent loss of heat and the entrance of air. The fire boxes are made by setting the brick in the kiln in such a way as to form arches, which extend through the kiln from side to side. The fuel is placed in these arches from openings in the side walls. The top of the kiln is covered with a layer of brick laid flatwise and close together. The platting, as this layer is called, is sometimes partly or wholly covered with sand or clay, and the heat is directed by moving this loose material from point to point. The brick are protected from the weather during the setting and burning by a shed roof raised upon poles, which extend several feet above the top of the brick. The brick are laid in from 40 to 50 courses.

Scove kilns are employed mostly for burning common brick. Vitrified brick are not easily burned in them because of the difficulty of securing a high temperature. They are not suitable for some kinds of clay for a similar reason.

Dutch or clamp kilns.—The Dutch or clamp type of up-draft kiln is in more common use than the scove kiln. These kilns have permanent side walls of a thickness sufficient to retain more heat than the scove kiln. It is possible to secure a higher temperature in them. The brick are stacked within the walls of the kilns, arches being left and the top platted as in the case of the scove kiln.

In the up-draft kiln several courses of brick at the bottom are likely to be overburned, while the top courses are underburned. The brick in the arches are generally slaggy, brittle and discolored. The percentage of hard burned brick varies with the care exercised in burning. Rarely more than 70 per cent of the kiln may be classed as number 1 brick.

DOWN-DRAFT KILNS.

In down-draft kilns the fire boxes are outside the walls, and the heat is conducted to the top of the kiln, and after passing through the brick is drawn off by flues at the bottom through one or more stacks. Some of the advantages of this type of kiln are: (1) labor saved in platting; (2) heat more thoroughly and completely distributed; (3) no extreme heat in contact with brick; (4) small amount of waste due to misshapen brick, because the highest heat is at the top where there is the minimum weight. From a single burn in this type of kiln as much as 90 per cent of hard burned brick has been obtained.

Beehive Kiln.—The beehive kiln is a circular down-draft kiln with an oval top. The kiln is supplied with one or more stacks. The gases are taken to these stacks from the bottom of the kiln by means of flues. It is essential that the kiln should have a uniform draft, and this is secured by construction of flues and arrangement of the wares within the kiln. The capacity of such kilns varies from 25,000 to 75,000.

Rectangular Kiln.—The down-draft rectangular kilns are of various types. They range in capacity from 150,000 to 300,000. They may be supplied with one large stack, into which more than one kiln may open. Each kiln may be supplied with two or more small stacks. The stacks are placed either at the side or end of the kilns.

Continuous Kilns.—Continuous kilns are built with the object of using the waste heat from the cooling brick to water-smoke the unburned brick. In shape they may be circular, oval or rectangular.

The only one used in Mississippi is rectangular in form. It consists of 12 chambers arranged in two rows and separated by permanent walls. Each chamber has a capacity of 70,000 brick. Producer gas is used as fuel. The gas is conducted by conduits from the gas producer to the various chambers. The waste heat from the chamber in which the burning has just been completed is used to water-smoke the one which has just been filled. The transfer of waste heat may be made between any two of the twelve chambers. The gases and water from the chambers are taken through the flues to one large stack, located near the end of the kiln.

CHAPTER V.

FUEL.

Fuel may exist as a solid, a liquid or a gas. Among the various substances used for producing heat are included wood, sawdust, straw, bagasse, turf, peat, lignite, bituminous coal, cannel coal, anthracite, coke, charcoal, petroleum, furnace oil, shale oil, creosote, tar oils, natural gas, coal gas, water gas, gasoline gas, naphtha gas and producer gas.

The principle combustible elements contained in these fuels are carbon and hydrogen. In the process of combustion these elements are oxidized. The carbon (C) unites with oxygen (O) in the proportion of one part of carbon to two parts of oxygen, if enough of the latter is present, otherwise one part of each combines, forming in the first case carbon dioxide (CO_2), in the second case carbon monoxide (CO). The hydrogen unites with oxygen in the proportion of two parts of hydrogen to one part of oxygen, forming water (H_2O). Both of these chemical unions result in heat.

The number of heat units produced varies with different substances. The heat-producing power of a pound of various substances is given by Parsons in "Steam Boilers," as follows:

TABLE 19.

CALORIFIC VALUE OF DIFFERENT FUELS.

Hydrogen gas		62,032
Carbon to carbon dioxide		14,500
Carbon to carbon monoxide		4,400
Carbon monoxide to carbon dioxide		4,330
Olefiant gas		21,344
Liquid hydrocarbons (oils), varying with weight	19,000 to	22,600
Charcoal, from wood		13,500
Charcoal, from peat		11,600
Wood, dry	average	7,800
Wood, 20% moisture		6,500
Peat, dry	average	9,950
Peat, 20% moisture		7,000
Coal, anthracite, best quality	about	15,000
Coal, anthracite, ordinary		13,000
Coal, bituminous, dry		14,000
Coal, cannel		15,000
Coal, ordinary poor grades		10,000

CLASSES OF FUELS.

Wood.

Wood is composed of organic and inorganic matter and water. The first is combustible, the others are non-combustible. In the process of burning the water is vaporized. The organic matter is consumed, *i. e.*, it is transformed into invisible gases. The inorganic matter remains in the ashes. When wood has been dried at 300° F. it contains about 99 per cent of organic matter and 1 per cent of inorganic matter. The organic matter consists of carbon, 49 per cent; oxygen, 44 per cent, and hydrogen, 6 per cent.

When wood is heated above the temperature necessary to drive off its moisture, gases are generated which ignite, producing flame. The amount of heat produced depends upon the moisture condition of the wood. When thoroughly dry a given amount of pine will produce just as much heat as the same amount of hickory. Pine, however, produces more flame than oak or hickory, and not as good a bed of live coals. Under ordinary yard conditions the oak or hickory may be said to exceed the pine by 25 per cent in the production of heat.

Wood under ordinary conditions contains 25 pounds of water, 74 pounds of wood and 1 pound of ash for every 100 pounds. The wood portion consists of 37 pounds of carbon, 4.4 pounds of hydrogen and 32 pounds of oxygen. In the process of combustion 4 pounds of hydrogen unite with 32 pounds of oxygen, forming water. This leaves about half of the wood substance, 37 pounds of carbon and .4 pounds of hydrogen, as elements of combustion. One hundred pounds of green wood contains about 50 pounds of water. This wood is capable of producing 270,000 heat units. A heat unit is the amount of heat required to raise one pound of water one degree Fahrenheit. The same amount of wood containing 30 pounds of water will produce 410,000 heat units. Air-dried wood contains about 20 per cent of water, and 100 pounds of such wood is capable of producing 500,000 heat units. When the same amount of wood contains only 10 per cent of water it will produce 580,000 heat units. One hundred pounds of kiln-dried wood, containing 2 per cent of water, will produce 630,000 heat units (Bull. 10, U. S. Forestry Div., 1895).

These facts point clearly to the desirability of having on hand a good supply of wood, so that the use of green or even half-dried wood may be avoided. The wood should not be decayed nor should it be wet or green if the highest heating efficiency is to be obtained. The moisture in the wood must be converted into water vapor and a great deal of heat is consumed in this conversion.

Many of the brick plants of the State rely entirely upon wood for fuel. Nearly all use wood for water-smoking. Oak and yellow pine are the more common kinds used, but in some plants ash, gum, willow and other species are used. The price of wood generally varies with the abundance of accessible timber and the condition of the local labor market. The average price per cord paid for wood is two dollars. The maximum price paid is two dollars and eighty-five cents, and the minimum is one dollar and twenty-five cents.

Coal.

Varieties of Coal.—There are a number of varieties of coal, ranging from nearly pure vegetable fiber in peat to the highly carbonized and crystalline anthracite. The names applied to these varieties are peat, lignite, cannel coal, jet, bituminous coal, semi-anthracite and anthracite. These coals vary in the amount of carbon and hydrocarbons which they contain and in other constituents.

Peat.—Peat is an accumulation of vegetable matter which is thought to represent the first stage in the formation of coal. It is generally brownish-black in color and of light weight. It contains from 50 to 60 per cent of carbon, 5 or 6 per cent of hydrogen, and from 35 to 40 per cent of oxygen. Its fuel ratio is only .47 as compared with 28 in some anthracite coals. It is formed from the accumulation of vegetable matter in bogs and low marshy areas. A great deal of peat is being formed in glacial lakes and ponds by the growth of spagnum moss.

Lignite.—On account of its low stage in the period of coal development lignite is sometimes called "green" coal, but because of its color it is also called "brown" coal. It is usually brown or brownish black in color. Some varieties on fresh fracture present a shiny surface. It generally disintegrates rapidly when exposed to the air and breaks up into small cubes or laminae. It is supposed to repre-

sent a more advanced stage in the development of coal than peat. It contains less volatile matter than the latter and more fixed carbon. Its fuel ratio is about 1.50. It usually contains from 35 to 45 per cent of fixed carbon; from 5 to 20 per cent of ash, and from 25 to 30 per cent of hydrocarbons.

Bituminous Coal.—Bituminous coal is a soft coal more dense than lignite, and represents a more advanced stage in coal formation. It is of a deep black color and frequently has a rather distinct resinous luster. It burns with a smoky flame. When exposed to the air it does not disintegrate as readily as lignite and contains a higher percentage of fixed carbon. Its fuel ratio is more than double that of lignite. Bituminous coal contains from 65 to 85 per cent of carbon, about 5 per cent of hydrogen, and about 15 per cent of oxygen. Its specific gravity varies from 1.20 to 1.40. Bituminous coals may be divided into two varieties, coking and non-coking. Coking coals when ignited with air excluded may be changed to coke.

Anthracite.—Anthracite is the hardest form of stone coal. It has a sub-metallic luster and breaks with a conchoidal fracture. It is brittle and of a shining black color. It has a specific gravity of from 1.57 to 1.67. It has a low percentage of hydrocarbons and a high per centage of fixed carbon. For this reason it is difficult to ignite and burns without much flame. It has a high calorific value and when burned under the proper conditions produces an intense heat. Its fuel ratio may be as high as 28. It contains from 90 to 95 per cent of carbon. The per cent of hydrocarbons is from 3 to 5 per cent. Anthracite coal represents the last stage in coal metamorphism and has lost all traces of its vegetable origin.

Determination of the Calorific Value of Coals.—In the determination of coal constituents moisture, volatile and combustible matter, fixed carbon and ash are determined by weight; sulphur, iron and phosphorous by analysis. The value of any substance as a fuel is usually found by determining the power of a given quantity of the substance to evaporate water. The heat-producing power of a substance is termed its calorific value. The calorific value of a fuel may be obtained by determining the number of pounds of water which it will convert into steam at the boiling temperature of water under a pressure of one atmosphere by the consumption of one pound of fuel.

The calorific value of fuels may be determined by the calorimetric method, the computation method and the direct method.

In the calorimetric method a definite amount of fuel to be tested is burned in a chamber surrounded by a definite amount of water. The rise of temperature of the water is registered by a thermometer. The proportion of the fuel to the water used is one part of fuel to every 967 parts of water. This proportion is used because when water is converted into steam at 212° F., 967° F., or 537.22 gram degrees or calories of heat, disappear as latent heat. If the temperature of 967 parts of water be raised one degree, enough heat has been employed to convert one part of water into steam at 212° F. Thus the rise of temperature of the water as recorded by the thermometer will indicate the number of parts of water capable of being converted into steam by the heat produced by the fuel.

In testing coal by the calorimetric method it is reduced to a fine powder in order to secure perfect combustion. Since the fuel must be consumed in a closed vessel it is necessary, in order that its combustion may be complete, to add compounds which will supply oxygen. To furnish the oxygen supply the coal is mixed with potassium chlorate ($KClO_3$) and potassium nitrate (KNO_3). The coal is consumed in a copper cartridge which fits into a cup-shaped receiver. A second copper cylinder with a valve tube at the upper end is placed over the first. A row of openings around the lower end of the second tube permits the escape of gases which are produced in the combustion. This apparatus is placed in a graduated glass cylinder which contains the water. The charge in the tube may be ignited by the use of a fuse of sufficient length to permit the apparatus to be placed in the vessel before the charge is ignited, and to cause ignition to take place by the time the apparatus reaches the bottom of the vessel. The charge may be ignited by means of an electric current.

The gases of combustion pass through the entire column of water and therefore their heat is lost to the water. The rate of combustion of the charge should be controlled so as to prevent too rapid evolution of gases, and at the same time the rate of burning should not be so slow as to cause loss of heat through radiation. The rate of combustion may be regulated by tamping the charge or by varying the amount of the oxygen-producing substances. As soon as the charge has been consumed the stopcock of the cartridge is opened so that

the water may come in contact with all parts of the cartridge and extract its heat. To facilitate extraction the furnace may be moved up and down in the water. The temperature of the water should be taken before the charge is burned and at the close of the burning. The temperature of the water should always be lower than the temperature of the room.

Allowances must be made for heat absorbed by the gases of combustion, for heat produced by the decomposition of the oxygen compounds, for the loss of heat by radiation and conduction, and for heat absorbed by the apparatus. The total loss of heat from these sources is from 10 to 15 per cent.

By means of the chemical analysis of coals and the use of the following formula, the calorific value of a coal may be computed:

Total heat expressed in B. T. U. = 14,500 C + 62,032 $(H-\frac{O}{8})$. The C is carbon, H is hydrogen and the O oxygen contained in the coal. They represent the amount by weight of each of these substances. The atomic weight of hydrogen is 1, the atomic weight of oxygen is 16. When they unite to form water they unite in the proportion of two H to one O or 2 to 16 (1 to 8). When present in the form of water they do not produce heat, hence $\frac{1}{8}$ of the oxygen is subtracted from the hydrogen. Another formula sometimes used is, total heat = 14,600 C + 62,000 $(H-\frac{O}{8})$ + 4,000 S, in which S represents the amount of sulphur present.

In the direct method of determining the calorific value, fuel is used to evaporate water under normal power plant conditions, and an accurate account of the number of pounds of coal used and the number of pounds of steam produced is kept for a definite period. In this way the evaporative power of different fuels may be determined and compared.

Since no coal is mined in Mississippi all our industrial plants are dependent upon other States for this class of fuel. Different parts of the State use coal derived from different sources. Some of the States from which our coal supply is drawn are Pennsylvania, Illinois, Indiana, Missouri, Arkansas, Tennessee, Kentucky and Alabama. We have very little information as to the calorific value of these different coals. The information given in the following table has been collected by Professor Albert Barnes, of the Mechanical Department of the Agricultural College of Mississippi. The tests were all made on Alabama coals:

TABLE 20.

CALORIFIC VALUES OF ALABAMA COALS.

Name of Coal.	*Kind of Coal.*	*Length of test in hours.*	*Weight of coal burned in pounds.*	*Weight of ash.*	*Weight of water evaporated.*	*Weight of water evaporated F. and A. 212° F.*	*Weight of water evaporated per unit of coal.*	*Cost of evaporating 100 pounds of water.*
Sterling L. Lanier, Agt	R. of M..	7	4,577	579	21,411	21,460	6.00	$0.02025
Gilnath Coal Co......	R. of M..	7	6,419	537	38,352	40,001	6.2	.0195
Corona Coal Co. (Annie Mae Mine)........	R. of M..	7	4,487	1,012	29,571	......	6.9	.0178
Carbon Hill coal (Kansas Mine).........	R. of M..	4	1,379	275	9,462	9,944	7.2	.0167
Hill Creek Coal Co. (Birmingham).....	R. of M..	8	5,603	311	34,250	......	6.417	.0195
Carbon Hill..........	R. of M..	12	6,236	.....	45,968	47,990	7.7	.0153
Tenn. Coal, Iron & R. R. Co..........	Lump...	10	5,642	486	47,514	49,604	8.7	.0150
Hill's Creek Coal Co..	R. of M..	18	13,386	11	99,730	......	7.73	.015925
Tupola Coal Co.......	R. of M..	4	2,833	.....	17,600	20,768	7.33	.0187

R. of M.—Run of Mine.

Mississippi Lignites.

As stated in the foregoing pages no coal is mined in Mississippi, and, to the best of our present knowledge, we have no coal other than lignite. There are numerous beds of lignite occurring in the Wilcox strata of the Eocene and in some other horizons. Below is given the analysis and the calorific values of a number of these lignites. The samples were collected by Dr. Calvin S. Brown of the State Survey and the determinations were made under the direction of Dr. W. F. Hand, State Chemist.

TABLE 21.

COMPOSITION OF MISSISSIPPI LIGNITES.

Constituent	*No.* 10	*No.* 14	*No.* 15	*No.* 20	*No.* 43	*No.* 46
Moisture..........	11.61	14.20	11.40	13.20	12.20	12.62
Volatile matter.....	34.61	35.24	32.61	40.16	46.27	40.85
Fixed carbon.......	42.47	41.80	37.00	31.24	30.86	39.94
Ash..............	11.31	8.76	18.99	15.40	10.67	6.59
Total..........	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur...........	2.66	.63	1.50	1.20	.76	2.05

CALORIFIC VALUES.

Calories per gr......	5595	5255	5112	5050	5096	5392
B. T. U. per pound..	10071	9450	9201	9090	9173	9706

COMPOSITION OF THE ASH FROM LIGNITES.

Constituent	*No.* 14	*No.* 23	*No.* 25	*No.* 43	*No.* 46	*No.* 48
Silicon dioxide......	29.10	22.95	63.65	51.82	35.00	22.66
Aluminum oxide	13.45	12.37	13.25	26.98	17.00	14.88
Iron oxide..........	21.00	19.00	10.95	7.12	29.00	20.62
Calcium oxide......	22.80	21.37	2.50	6.07	4.55	15.20
Magnesium oxide...	.19	.97	.90	.22	1.50	2.90
Sulphur trioxide....	8.53	14.70	4.46	5.45	6.34	19.89

Oil.

Mineral oils are now used for fuel in many industries. Petroleum is said to be used successfully in the burning of brick in some of the oil fields of the West. The oil is kept in tanks and fed into the fire box by means of an injector-nozzle. The blast from the nozzle produces a current of air which mingles with the oil and flame in the combustion chamber, thereby aiding combustion.

Petroleum, or crude oil, is a liquid of complex composition. It is composed largely of a mixture of hydrocarbons. There are two general classes of petroleum, viz.: those having a paraffin base and those having an asphaltum base. Chemically petroleum is composed of carbon, hydrogen and oxygen. The percentage of carbon varies from 82 to 87 per cent; hydrogen from 12 to 14.8 per cent, and oxygen from 1 to 6 per cent. The specific gravity ranges from .80 to .983. A gallon of petroleum weighs from 6.5 to 7.8 pounds. A pound of oil will produce from 19,000 to 22,000 heat units and will evaporate from 19.6 to 22.7 pounds of water.

The results obtained from the use of petroleum for boiler fuel at the World's Fair at Chicago in 1893 were as follows:

TABLE 22.

AMOUNT AND COST OF PETROLEUM FOR BOILER FUEL.

Consumption of oil per hour..................................	22,792 pounds
Water evaporated from 212° F. into steam at 125 pounds, per pound of oil..	14.25
Equivalent evaporation from and at 212° F..................	14.88
Cost of oil per hour...	$56.20
Cost of oil per boiler horse-power per hour....................	.0057
Cost of labor per boiler horse-power per hour..................	.0006
Cost of boiler horse-power per hour..........................	.0063

Repeated experiments seem to have demonstrated that in evaporative power one pound of oil is equivalent to two pounds of coal. The causes of the superiority of oil are summed up by Parsons in *Steam Boilers* as follows:

"1. The combustion of the liquid fuel is complete, whereas that of coal is not, consequently in the former case there is no lost heat in smoke or soot.

"2. There are no ashes or clinkers, and consequently no fires to clean with the accompanying loss of heat and drop in the steam-pressure.

"3. The boiler-tubes are always free from soot and clean, and therefore always in the best condition for transmitting the heat from the gases passing through them to the water of the boiler.

"4. The temperature of the escaping gases may be considerably lower than is required to create the draft necessary for coal-firing.

"5. The admission of air being under complete control, and the fuel being burned in fine particles in close contact with oxygen of the air, only a small excess of air above that actually necessary for the combustion of the fuel is required. With coal, in order to insure as complete combustion as possible, a very much larger excess of air is required."

Gas.

Natural gas has not been discovered in appreciable quantities in Mississippi or in the territory immediately adjacent. For this reason this form of fuel is not used in any of our industrial plants. Artificial gas, called producer gas, is used in one of the clay plants of the State for burning its ware. The gas is manufactured by injecting steam upon a bed of burning soft coal. The gas is used in a chambered continuous kiln. By the use of this form of fuel there is said to be a large saving in labor and fuel. Twenty-six hundred feet of natural gas is equivalent, in heating power, to a good average ton of coal. It would, however, require 100,000 feet of some of the poorer artificial gases to be of equal value.

The composition of natural gas and some of the artificial gases is given in the following table from Kent's Mechanical Engineer's Pocket-book:

TABLE 23.

COMPOSITION OF FUEL GASES.

Constituent	Natural gas	Coal gas	Water gas	Producer-gas Anthracite	Producer-gas Bituminous
CO	0.50	6.0	45.0	27.0	27.0
H	2.18	46.0	45.0	12.0	12.0
CH_4	92.60	40.0	2.0	1.2	2.5
C_2H_4	.31	4.0	....	....	.4
CO_2	.26	.5	4.0	2.5	2.5
N	3.61	1.5	2.0	57.0	56.2
O	.34	.5	.5	.3	.3
Vapor	...	1.5	1.5	....	....
Weight in pounds of 1,000 cubic feet	45.60	32.0	45.6	65.6	65.6
Heat units in 1,000 cubic feet	1,100,000	735,000	322,000	137,455	156,917

The same author gives the following fuel values for the different kinds of gaseous fuels:

TABLE 24.

FUEL VALUE OF GASES.

Kind of gas	No. of heat units in 1,000 cubic feet used	No. of heat units in furnaces after deducting 25% loss	Average cost per cubic foot	Cost of 1,000,000 heat units obtained in furnaces
Natural gas	1,000,000	750,000	....	....
Coal-gas, 20 candle power	675,000	506,250	$1.25	$2.46
Carburetted water-gas	646,000	484,500	1.00	2.06
Gasoline-gas, 20 candle power	690,000	517,500	.90	1.73
Water-gas from coke	313,000	234,750	.40	1.70
Water-gas from bituminous coal	377,000	282,750	.45	1.59
Water-gas and producer-gas mixed	185,000	138,750	.20	1.44
Producer-gas	150,000	112,500	.15	1.33
Naphtha-gas, fuel 2½ gallons, per 1,000 feet	306,365	229,774	.15	.65
Coal, $4.00 per ton, per 1,000,000 heat units utilized	......	....	....	.73
Crude petroleum, 3 cents per gallon, per 1,000,000 heat units	....	....	....	.73

CHAPTER VI.

PROPERTIES OF BRICK.

EARLY HISTORY OF BRICK.

According to present historical knowledge clay was first employed for structural purposes in Babylonia.* This country is partly an alluvial plain bordering on the Persian Gulf. The plain is drained by the Tigris and the Euphrates rivers and is probably very similar in origin to the Yazoo basin of the Mississippi. This plain, like others of its kind, is devoid of ledges of hard rock which can be used for structural purposes. So the early inhabitant, not finding the rock with which to construct his house, was compelled to employ a substitute. Hence brick—another proof that necessity is the mother of invention. Down beneath the drifting sands of the plain the early inhabitant of Babylonia found a plastic clay which he could mold and fashion into brick. Thus brick and other clay wares were manufactured, probably 8,000 years before the beginning of the Christian Era.

The first brick were irregular rectangular masses of clay dried in the sun. Brick were not burned until about 4500 B. C. The first burned brick were small, flat upon one side and rounded upon the other, or plano-convex brick with rounded corners. These brick were set upon edge in the wall, the spaces being filled in with mud or bitumen. Forty-five varieties of these early brick have been discovered in excavations recently made in Bismya.

BRICK TESTS.

In order to determine the wearing qualities of brick a series of tests is employed. These tests determine the amount of load required to break the brick crosswise, transverse strength; the amount of load required to crush the brick, crushing strength; the number of pounds of pull the brick will stand, tensile strength; the

* Banks, Clay Products of Early Babylonia, Clay Worker for January, 1907.

amount of water the brick will absorb, absorption test; the amount of knocking about required to destroy the brick, impact test; and the amount of freezing the brick will stand without deterioration. These tests are not so essential in small buildings, but in large structures, and especially in paving work, they are very essential. However, only four are considered of leading importance, viz.: transverse strength, crushing strength, impact strength, absorption.

Crushing Strength.

The crushing strength of a brick is expressed in the number of pounds of pressure per square inch of surface that a brick will stand. The object of the test is to determine how much load the brick are capable of supporting when placed in a wall. The crushing strength of brick varies from 500 pounds to 15,000 pounds per square inch.

The weight of an ordinary brick is about 5 pounds. When laid flatwise a standard brick has an exposed top area of 32 square inches. Each brick laid upon this surface exerts a pressure of about $\frac{1}{6}$ of a pound per square inch. Every six bricks then exert a pressure of 1 pound per square inch. Therefore, in a wall 100 feet high the pressure exerted upon the bottom layer of brick, if the weight of the brick only is considered, is only 100 pounds per square inch. From these facts it will readily be seen that the crushing strength of brick is not likely to be overtaxed in construction work. The crushing strength of brick is tested in machines specially constructed for the test. In soft-burned brick the crushing strength may be as low as 40 pounds per square inch.

In making the test, parallel edges of the half of a brick are ground smooth and the brick is then placed between the bearing plates of the machine. The load is increased gradually until the strength of the brick is reached when it falls into pieces with a loud report.

Absorption.

Brick are porous. That is, they contain spaces not occupied by clay particles. The degree of porosity is determined by the amount of water that the brick will absorb. The porosity of a brick may depend upon a number of factors. It may depend upon the character of the clay used. A coarse, sandy clay will produce a more porous brick than a more aluminous clay. It may depend upon the degree

of burning, as a soft-burned brick will absorb more than a hard-burned brick. It may also depend upon the process of molding. Soft-mud brick, as a rule, are more porous than stiff-mud brick.

The percentage of absorption in Iowa common brick ranges from 9.5 per cent to 22.7 per cent. One paving brick tested absorbed 4.7 per cent.*

New Jersey soft-mud brick range from 5.36 per cent to 18.64 per cent, while stiff-mud brick range from 1.34 per cent to 14.29 per cent.†

The following tests were made upon some bricks from this State. The samples tested, after being carefully dried, were weighed and then immersed in water for 48 hours. Upon being taken from the water, the moisture adhering to their surfaces was removed and they were reweighed. The difference between the weight of the dry brick and the wet brick gave the amount of water absorbed. By dividing this difference by the weight of the dry brick the percentage of absorption was determined.

TABLE 25.

ABSORPTION TESTS OF MISSISSIPPI BRICKS.

Locality	*Color*	*Make of brick*	*Per cent of absorption*
Stonington	Red	Pressed	10.52
Yazoo City	"	"	15.00
" "	"	"	15.00
" "	"	"	15.00
Oxford	"	"	14.09
"	"	"	12.50
"	"	"	12.76
"	"	"	13.04
"	White	"	15.00
Starkville	Red	Stiff mud (repressed)	22.22
"	"	" "	10.52
"	Chocolate	" "	5.00
"	Iron color	" "	5.26
"	"	Stiff mud	8.10
"	Red	"	5.26
Columbus	Chocolate	"	21.21
"	Red	"	15.74
Amory	Chocolate	"	15.00
"	Red	"	9.75
Maben	Chocolate	"	8.80
"	Red	"	16.86
"	White	"	26.86

It is thus seen that the percentage of absorption in dry-pressed brick ranges from 10.52 to 15 per cent. The percentage of absorption

*See Vol. XIV, Iowa Geol. Sur., p. 595.
†See Vol. VI, N. J. Geol. Sur., pp. 254–5.

in repressed brick ranges from 5 to 22.22 per cent. The percentage of absorption in stiff-mud brick ranges from 5.26 to 26.82 per cent. In the manufacture of these brick different kinds of clay were used and the degree of burning varied. All of those exhibiting a high percentage of absorption were soft-burned.

Impact Strength

Rattler Test.—Brick for the rattler impact test are placed in a polygonal cast-iron barrel which is made to revolve on trunnions. The length of the barrel is 20 inches and its diameter is 28 inches. It is a regular polygon of 14 sides. The brick are placed in the barrel together with a charge of cast-iron blocks. The barrel is then moved at a certain speed for a definite number of hours. The strength of the brick is then estimated by the amount of loss it has sustained due to abrasion. The charge consists of 12 brick and 300 pounds of iron blocks of two sizes. First, cubes of 1½ inches in diameter having a collective weight of 225 pounds; second, blocks 2½ inches square and 4½ inches long with rounded edges and a collective weight of 75 pounds. The number of revolutions required for the test is 1,800 at the rate of 80 per minute. The brick must be perfectly dry. The loss is computed as per cent of the dry brick and the average of two tests taken

The rules for this test, adopted by the National Brick Manufacturers' Association, are as follows:

"The standard rattler shall be 28 inches in diameter and 20 inches in length, inside measurements. Other dimensions may be employed between 26 and 30 inches diameter and 18 to 24 inches length, in which case the dimensions should be stated in reporting the test. Longer rattlers may be employed by the insertion of a diaphragm.

"The barrel should be supported on trunnions at the ends with no shaft running through the rattling-chamber. The cross section should be a regular polgyon of 14 sides. The heads shall be of gray cast iron, not chilled or case-hardened. The staves shall preferably be composed of steel plates, as cast iron peens and ultimately breaks from the wearing action on the inner side. There shall be a space of one-fourth an inch between the staves for the escape of dust and small pieces. Machines having from 12 to 16 staves may be employed, with openings from ⅛ to ⅜ inch, but these variations from the standard should be mentioned in an official report.

"The charge shall consist of but one kind of brick at a time, nine paving blocks or twelve bricks being inserted, together with 300 pounds of cast-iron blocks. These shall be of two sizes, 75 pounds being of the larger and 225 pounds of the smaller size. The larger size shall be about 2½ inches square and 4½ inches long, with slightly rounded edges. All blocks shall be replaced by new ones when they have lost 10 per cent of their original weight.

"The number of revolutions shall be 1,800 for a standard test at a speed between 28 and 30 per minute.

"The bricks shall be thoroughly dried before testing. The loss shall be calculated as per cent of the weight of the dry bricks composing the charge, and no result shall be considered as official unless it is the average of two distinct and complete tests made on separate charges of brick." (Materials of Construction, Johnson, p. 461a.)

Tensile Strength.

The tensile strength of ordinary brick varies from 40 to 400 pounds per square inch. The test is made by placing the specimen in the jaws of a machine and measuring the amount of pull necessary to break the section. The tensile strength of a large number of Mississippi brick clays was tested in both the raw and the burned state. These results are recorded under the discussion of the individual clays. No tests have been made upon the manufactured product of the various plants. The tensile strength of some of the burned clays ranges as high as 800 pounds per square inch.

Transverse Strength.

The transverse strength of a brick is measured by the load it will sustain when unequally supported. For example, suppose a brick to be supported at each end and a load applied to a point midway between the supports. When the load added reaches the transverse strength of the brick the brick will be broken crosswise. The modulus of rupture is calculated by the use of a formula in which

R = Modulus of rupture.
W = Pressure of load.
l = Distance between supports.
b = Breadth of brick.
h = Thickness of brick.
and $R = \frac{3Wl}{2bh^2}$

Now, if a weight of 3,000 pounds be applied to a brick 4 inches wide and 2 inches thick, where the distance between the supports is 4 inches, its transverse strength will be as follows:

$$\frac{3\times 3000\times 4}{2\times 4\times 2} = 1{,}125 \text{ pounds.}$$

Weight of Brick.

Common brick, having a size of $8\frac{1}{4}$ x 4 x 2 inches, have an average weight of $4\frac{1}{2}$ pounds. One thousand of such brick have a weight of 4,500 pounds or 2.01 long tons. Pressed brick of standard size have an average weight of 5 pounds and weigh 2.23 tons per 1,000.

The average weight of 10 Mississippi pressed brick is 5.6 pounds. The average weight of 10 repressed brick of stiff-mud make is 4.7 pounds. The average weight of 10 stiff-mud brick is 4.6 pounds. These brick represent different kinds of clays and different sizes of molds.

Size of Brick.

The size of a standard brick is $8\frac{1}{4}$ inches long by 4 inches wide by 2 inches thick. A brick of this size contains 66 cubic inches. It requires 26.2 bricks of standard size to make 1 cubic foot and 707 standard brick to make 1 cubic yard.

The following table exhibits the sizes of some Mississippi brick. These brick vary in volume from 64 cubic inches to 95 cubic inches. One, alone, falls below the volume of a standard brick, and that one by 2 cubic inches only.

TABLE 26.

SIZE OF SOME MISSISSIPPI BRICK.

Number of Sample	*Color*	*Hardness*	*Size—Inches*	*Make*	*Formation*	*Volume*
Number 1	Red	Medium	$8\frac{1}{2} \times 4 \times 2\frac{1}{2}$	Pressed	Residual loess (B. loam)	85 cubic inches
" 2	Red	Hard	$7\frac{7}{8} \times 3\frac{11}{12} \times 2\frac{5}{12}$	"	" " "	74 "
" 3	Red	Medium	$8\frac{1}{2} \times 4\frac{1}{6} \times 2\frac{11}{16}$	"	" " "	95 "
" 4	White	Medium	$8\frac{1}{4} \times 4\frac{1}{12} \times 2\frac{1}{2}$	"	Wilcox	84 "
" 5	Iron black	Hard	$7\frac{11}{12} \times 3\frac{3}{4} \times 2\frac{1}{6}$	Repressed	Selma residual	64 "
" 6	Chocolate	Hard	$7\frac{11}{12} \times 3\frac{5}{6} \times 2\frac{1}{4}$	"	" "	68 "
" 7	Red	Medium	$8 \times 4 \times 2\frac{1}{6}$	"	" "	69 "
" 8	Chocolate	Medium	$8\frac{1}{6} \times 4 \times 2\frac{1}{3}$	Stiff mud	Y. loam (2d bottom)	76 "
" 9	Bright red	Soft	$7\frac{11}{12} \times 3\frac{11}{12} \times 2\frac{5}{12}$	"	" "	74 "
" 10	White	Soft	$8 \times 3\frac{3}{4} \times 2\frac{1}{3}$	"	" "	70 "
" 11	Dark red	Medium	$7\frac{5}{6} \times 4 \times 2\frac{5}{12}$	"	" "	75 "
" 12	Iron black	Hard	$8\frac{1}{12} \times 3\frac{5}{6} \times 2\frac{1}{6}$	"	Selma residual	67 "
" 13	Red	Medium	$7\frac{11}{12} \times 3\frac{3}{4} \times 2\frac{1}{4}$	"	" "	66 "
" 14	Chocolate	Hard	$8\frac{3}{4} \times 4\frac{1}{12} \times 2\frac{5}{12}$	"	Y. loam (2d bottom)	83 "
" 15	Red	Medium	$8\frac{7}{8} \times 4\frac{1}{2} \times 2\frac{1}{3}$	"	" "	81 "
" 16	Chocolate	Hard	$8\frac{1}{4} \times 3\frac{11}{12} \times 2\frac{1}{4}$	"	" "	72 "
" 17	Red	Medium	$8\frac{1}{6} \times 4 \times 2\frac{1}{4}$	"	" "	73 "
" 18	White	Soft	$8\frac{1}{6} \times 4\frac{1}{6} \times 2\frac{7}{12}$	"	Wilcox	87 "

Variation in the size of brick may be due to a number of factors, viz.: (*a*) size of the die, (*b*) wearing of the die, (*c*) shrinkage of the clay, (*d*) degree of burning, (*e*) load in kiln, (*f*) method of molding.

The dies used by different manufacturers are not of uniform size. Even in the same machine the dies may vary in size, depending usually upon the desire of the manufacturer for a larger or smaller brick. The wearing of the die will increase the size of the brick. Some manufacturers put in a new die at the beginning of each new kiln. The last brick made by an old die are sometimes as much as $\frac{1}{8}$ of an inch wider and thicker than the first ones molded.

Variability is produced by a difference in the amount of shrinkage in clays. Even in clays from the same pit there may be a marked difference in the shrinkage. In surface deposits the top clays shrink less than the bottom clays. Numbers 3 and 4 of the table given above were molded by the same machine and burned to the same degree. The variation in volume (11 cubic inches) is due entirely to the difference in the shrinkage of the clays. No. 3 was made from the brown loam and No. 4 from the Wilcox. Nos. 14 and 15, made by the same machine under uniform conditions, represent the variability produced by different degrees of burning.

Three sizes of brick may be produced in the same kiln. In an up-draft kiln the top brick are larger than the middle brick, and the latter larger than the lower brick. Exceptions may be produced in some kilns by the expansion of certain kinds of clay at the point of viscosity.

The size of a brick will also depend upon the amount of load it sustains in the kiln. The weight of superincumbent brick may compress the lower brick, when near the point of viscosity, causing a loss of width which may be partly compensated by a gain in length, but resulting on the whole in a loss of volume. Another cause for variation in size of brick will be found in the different methods of molding employed, viz.: whether soft-mud, stiff-mud or dry-press.

The importance of the size of brick to the consumer is readily demonstrated. For instance, it requires 26.2 bricks of the standard size to make 1 cubic foot and 707 bricks for 1 cubic yard. Now, if the brick are smaller by one-fourth inch in each dimension there will be a decrease of 13.5 cubic inches in volume per brick, and it will

require 25 per cent more brick for each cubic foot. The cost of building will thus be increased about 25 per cent.

As will be seen from the table, only one of the Mississippi brick falls below the standard size. This one represents the minimum size of that manufacturer, and the small size is due to excessive shrinkage in the clay, not enough non-plastic material being used in that run.

Number of Brick in Construction Work.

The number of brick of standard size ($8\frac{1}{4}$ x 4 x 2 inches) required in walls, allowance being made for waste:

1	square	foot	of a	wall	1	brick	thick	will	require	14	brick.
1	"	"	"	"	1½	"	"	"	"	21	"
1	"	"	"	"	2	"	"	"	"	28	"
1	"	"	"	"	2½	"	"	"	"	35	"
1	"	"	"	"	3	"	"	"	"	42	"

An English rod of brick contains 306 cubic feet and requires 4,500 brick.

One bricklayer with a helper will lay 1,500 brick in a day of ten hours when working on an ordinary wall. In face or front work, he will lay from 1,000 to 1,200.

The number of brick of standard size required per square yard in sidewalk work is 38 brick, providing they are placed flatwise. If placed edgewise the number required is 73, and when placed endwise 149 are required. One man with a helper will place 2,000 brick in a day of ten hours.

Varieties of Brick in a Kiln.

In the down-draft kiln the top course is generally discolored with soot and ashes. The first two or three courses are sometimes brittle. As a usual thing these courses contain very hard brick, because they are subjected to the highest heat of the kiln. They may, however, because of rapid cooling, be deficient in toughness.

The shape of the brick of the top courses in a down-draft kiln is generally excellent, for the reason that there is no weight resting upon them to cause distortion. The conditions of burning make them very desirable for sewers and foundations.

The lower courses in down-draft kilns are liable to be under-burned or soft brick. The number of courses of soft brick, varying with the conditions of the burning, may be from two to ten courses. They are generally classified as No. 2 building brick and are used for backing.

The courses between the brittle top courses and the soft lower courses are classed as hard-burned brick. They are characterized by a tough, homogenous, hard body and a fairly uniform color.

The degree of vitrification is determined by the depth of the kiln marks, the limits for hard brick being placed at $\frac{1}{8}$ and $\frac{3}{8}$ inch.

CHAPTER VII.

IMPERFECTIONS OF BRICK.

Imperfections of brick arise from a number of causes. The character and causes of some of the more common imperfections in brick are discussed in the following pages.

DEFECTS OF FORM.

SWOLLEN BRICK.

If the temperature of a brick is raised rapidly so that the outside becomes vitrified before the gases have been expelled, swollen brick will result. For example, suppose a brick contains a high per cent of calcium carbonate ($CaCO_3$). By the action of heat the $CaCO_3$ is converted into CaO (lime), and CO_2 (carbon dioxide), a gas. Now, if the outside of the brick reaches the density and viscosity of vitrification before the gas has all been expelled, the gas will be temporarily confined, and the expansion due to the confined gas will cause a swelling of the brick. This is especially likely to occur in the case of the occurrence of nodules of calcium carbonate or pyrite in the clay.

Clay also contains gypsum, calcium sulphate, which when heated evolves a gas. The chemical symbol for gypsum is $CaSO_4$, $2H_2O$. At a temperature varying from 212° F. to 932° F. the water (H_2O) is drawn off. At a still higher temperature the SO_3 (a gas) is separated, leaving CaO. If the outsides of the brick have reached the stage of viscosity at the time of the evolution of the gas swollen brick will result.

Some clays which are used in the manufacture of brick contain very appreciable quantities of organic matter. In the combustion of this organic matter gaseous products (hydrocarbons) are formed. If the outer surface of the brick should become viscous before the hydrocarbons are all expelled, the expansive force of these gases may result in swollen ware. (A pound of carbon requires $2\frac{2}{3}$ pounds of oxygen for combustion and produces $3\frac{2}{3}$ pounds of CO_2.)

WARPED BRICK.

Warping of brick may be caused either in drying or in burning. Brick so placed in the dryer that they will dry faster upon one side than the other may warp. This is a common result when soft-mud brick are left too long upon the flat side in the open yard. Less often they warp when placed upon pallets in racks. Strong currents of air may produce such results even in the racks.

Warping may result in the kilns when one side of a brick reaches the point of viscosity while the other side is still solid. Warping of brick in a kiln is commonly produced by careening, that is, is a differential settling of the brick in the kiln. The brick in this section of the kiln soften, shrink and settle. Since the brick in the kiln are all bound together in setting, the unequal settling will cause some of them to be stressed. If they are soft enough to yield to the strain they will be warped, otherwise they will be broken. Careening is caused by faulty methods of firing. Too rapid firing in some parts of the kiln causes the heat to be drawn to one place, and chokes up parts of the kiln with smoke or soot.

CRACKED BRICK.

Too rapid drying results in differential shrinkage which produces cracks. When moisture is removed from the brick too rapidly it causes the outside to shrink more rapidly than the interior, thus subjecting the exterior to stretching, which results in breaking. Extremely sandy and extremely plastic clays are, as a rule, tender and require careful handling in the first extraction of moisture. Exposure to full and free circulation of the air is generally fatal to such clays. They should be protected from drafts for from six to twelve hours when first placed to dry. If a steam dryer is used, they should first be put into a tempering chamber and thoroughly heated before being placed in the dryer where the circulation might otherwise remove the moisture too rapidly.

Differential shrinkage, caused by too rapid loss of moisture along laminations, is another cause of cracks in brick. This is a common defect in certain clays used for the manufacture of brick by the stiff-mud auger-type machine. Frequently the laminations which remain almost invisible in the air-dried brick will be greatly developed in burning, due to the accumulation of gases along the laminæ. They

are generally more harmful in side-cut brick than in end-cut. The clay is generally too plastic and should be tempered by the addition of non-plastic material. In surface deposits the bottom clays are likely to produce laminæ, and more of the top clay should be added. Laminations may be at least partly obliterated by repressing.

The presence of lime nodules which are calcined in burning frequently cause cracking and bursting of the brick. The heat and stresses set up by the hydration of the lime after the brick leave the kiln are the immediate causes. Brick containing these blebs of quick lime may be taken from the kiln in perfect condition, but after being exposed to a moist atmosphere the slaking of the lime will cause the brick to pop open. The product of an entire kiln may thus be lost. The amount of lime may not be excessive if it is ground fine and thoroughly mixed in the clay. The clay, however, could not be burned at a high temperature because of the fluxing action of the lime. According to Reis, calcareous clays containing as high as 20 per cent of calcium carbonate have been successfully used in the manufacture of clay wares.

DEFECTS OF COLOR.

LIGHT COLOR IN RED-BURNING BRICK.

Light color in red-burning brick may be the result of a number of conditions. The red color of burned clay is due to the oxidation of the iron compounds in the clay. The iron may be changed to ferrous oxide (FeO) or to ferric oxide (Fe_2O_3). Once changed to the oxide condition it will so remain until the point of vitrification is reached, when the iron may unite with silica and form silicates of iron. Light-colored brick may result if the total amount of iron in the clay is small. The amount of iron in clays ranges from less than 1 per cent in white-burning clays to 5 per cent or more in red-burning clays. The clay may contain the amount of iron requisite for a red-colored product and yet the ware be light in color because it has been burned at a low temperature.

The presence of lime in a clay may cause a light-colored product, notwithstanding the fact that a larger amount of iron is present than would produce a red-colored ware under normal conditions. Clay No. 32 from West Point contains 8.75 per cent of iron—double the

amount necessary, under normal conditions, to produce red brick. The analysis of the clay shows the presence of 3.75 per cent of calcium oxide. This amount is abundantly sufficient in this instance to destroy the effect of the iron oxide and produce a pale yellow brick.

Deficiency in the amount of oxygen during the burning may be the cause of light colors in burned clay wares. If iron is oxidized in an atmosphere deficient in oxygen the ferrous compound (FeO) will be formed. Ferrous oxide produces a green color. Ferric oxide is red or purple. Oxygen deficiency may arise from insufficient draft in the kiln. Not enough oxygen is supplied to form the ferric compound. The conditions may be aggravated by the presence of carbonaceous matter in the clay. The carbon in the process of oxidation would rob the iron of oxygen and reduce it to the ferrous state.

EFFLORESCENCE.

Brick sometimes have their surfaces discolored by a white or yellowish substance called whitewash or efflorescence. This whitewash may appear on the brick during the process of drying. The water which comes from the interior of the brick by capillary attraction is evaporated at the surface and leaves behind its soluble salts which form the efflorescence.

Kiln White.—Brick which do not develop any efflorescence during the process of drying may do so during the burning period. The form of whitewash, called kiln-white, is composed of sulphates of calcium, magnesium, potassium, sodium and aluminium. All except the first named occur in very small quantities. These soluble salts may be present in the clay, they may be in the water used for tempering and they may be developed by reactions between kiln gases and constituents of the clay.

The calcium sulphate in clays is often developed by the oxidation of iron pyrites which produces sulphuric acid, which in turn attacks the calcium carbonate of the clay forming calcium sulphate. For the chemical reaction which takes place see page 55, under Gypsum. This salt is then deposited on the surface during the drying process. These salts are not liable to occur in the upper part of surface clay deposits but they are sometimes abundant in residual clays formed from limestone, especially along the line of contact.

Kiln-white is also produced by the union of sulphur dioxide from the fuel gases with calcium or magnesium in the clay products. Frequently the water used in tempering clay is taken from ponds which are made on or near limestone and clay contact. Such water is generally the source of efflorescence.

Wall-White.—Efflorescence which appears upon the brick after they are placed in the wall is termed wall-white. Wall-white is produced by the deposition of soluble salts on the surface of the brick through the evaporation of absorbed water from the interior of the brick. These salts are formed by chemical reactions taking place during the process of burning. The chemical reactions are usually between sulphuric acid derived from fuel gases and calcium or magnesium in the clay. After the brick are placed in the wall they may absorb water, which will take these salts into solution. The salts are then drawn to the surface of the brick by capillarity and, when the water is evaporated, they are left as a white, powdery coating on the surface of the brick.

The following means of prevention of kiln-white have been suggested:*

"1. Use the clay before the soluble salts form, *i. e.*, unweathered. Since the sulphates in the clay nearly always result from the weathering of its pyrite, it is often possible to avoid the whitewash simply by using the clay fresh from the bank, rejecting that which has been exposed to the weather any length of time. This is only possible with clays that lie below the permanent water level. This use of the clay, however, leaves the pyrite in the clay, and as has been shown, it will sooner or later come out as efflorescence on the walls. While the manufacturer is thus enabled to produce a clean brick, he is simply passing the trouble on to the user of his wares.

"2. Remove the soluble salts entirely from the clay, *i. e.*, weather it thoroughly, thus causing the washing out of the salt. Since the whitewashing salts are all soluble, or can be rendered so by weathering, it is possible to remove them entirely by exposing the clay to the action of the air, rain and frost as long as is necessary. As the action is slow and will not penetrate the clay unaided, the clay should be spread in thin layers and worked over occasionally. As the object is to remove

*Jones in Brick, Vol. XXVI, p. 89.

the salts entirely, the ground upon which the clay is spread should slope enough to thoroughly drain the water away from the clay after it has done its work. This process not only removes the whitewashing salts but also increases the plasticity of the clay. The process takes several months and is too expensive on that account for most brick plants.

"It is possible to remove those soluble salts already formed in the clay by washing it. In using this process it must be borne in mind that the object is to remove the impurities and soluble salts and consequently a good supply of water must be at hand. In one case, at least, the water was being used over and over again until gypsum crystals of good size could be found quite plentifully in the storage tank of the washer. As in the process of weathering, the washing not only removes the salts but gives a more homogenous and better product. Its only disadvantage is the increased cost, which need not be large if a good supply of water is to be had.

"3. Transform the soluble salts to a harmless form by precipitation. The method in most common use to transform the soluble into insoluble sulphates is to mix amounts of barium carbonate or chloride with the clay. When either of these salts is introduced into a clay containing soluble sulphates, the barium combines with the sulphur and forms barium sulphate, one of the most insoluble compounds known.

$$BaCO_3 + CaSO_4 = BaSO_4 + CaCO_3$$
$$BaCl_2 + CaSO_4 = BaSO_4 + CaCl_2$$

"As the barium sulphate is very insoluble and is not decomposed during the burning the sulphur is firmly locked in the interior of the brick as long as the brick endures.

"Barium carbonate is also a very insoluble compound and must be ground finely and very thoroughly mixed with the clay to accomplish the end that is sought. A German writer recommends that it be ground in a tube mill together with fine sand, which has the effect of soon reducing it to the very fine powder that is wanted. The correct amount, which necessitates a chemical analysis for its determination, is then added to the clay as it enters the pug mill. The carbonate is perfectly safe to use, as neither an excess of the barium nor the calcium carbonate formed will cause efflorescence. Its success depends

upon the thoroughness with which it is ground and mixed with the clay.

"The chloride, on the other hand, is soluble and consequently does not need much care in grinding and mixing. As it is soluble, it is rather dangerous to use, for any excess is carried to the surface of the brick and forms there a whitewash with the sulphur in the kiln gases. Its by-product, calcium chloride, is also soluble and is liable to form whitewash in the same way. The Germans frequently use both the carbonate and the chloride, adding enough of the chloride to overcome most of the whitewash, and depending upon the carbonate to take care of whatever whitewashing salts remain.

"4. Prevent the concentration of the salts on the surface of the brick by rapid firing. It is often possible when clay shows a tendency to whitewash, to hold the whitewash inside the brick by drying as quickly as possible. The mechanics of this is simple, and depends on the property of capillary tubes. When the brick is dried quickly the water is evaporated before the salt reaches the surface in sufficient quantities to cause trouble. When the clay will not permit of rapid drying the method cannot be used.

"5. Remove the whitewash in the kiln by the use of a reducing flame. The sulphates once formed cannot be decomposed or removed in an oxidizing flame at any temperature ordinarily reached in the kiln. In a reducing flame the sulphates are reduced at temperatures of 1,832° F. to sulphides. The bases enter into combination with the silicates of the brick, while the sulphur is driven off with the gases. By the use of this principle it is possible to drive off the whitewash by finishing the burn under reducing conditions. This has the disadvantage of darkening the color of the brick and also causing the slagging of the iron into a ferrous silicate, thus starting fusion prematurely.

"6. Coat the brick with some combustible substance that will remove the whitewash as it burns off. A method in vogue in Germany is to coat the brick on the face, as they leave the machine, with coal tar or wheat flour. As this burns away it has a strong reducing action and removes the whitewash as just explained."

DEFECTS OF STRUCTURE.

LAMINATIONS.

The laminations often occurring in stiff-mud brick are produced by the auger. The clay as it is forced over the smooth surface of the auger receives polished surfaces which may have failed to adhere perfectly when the clay is forced through the die. Then there is a differential movement of the clay through the die. The clay in the center of the die moves faster than at the sides because of the friction of the clay against the walls of the die. This differential movement also tends to increase laminations. This form of imperfection is more pronounced in plastic clays. If the bonding power of the clay is adequate, non-plastic material may be added to remedy the defect. The laminations may not be perceptible when the brick are first taken from the machine. During the process of drying the moisture will escape more freely along the lines of the laminations and the differential shrinkage so produced causes the "shells" of clay to separate.

Repressing, while not always completely destroying laminations, may greatly improve the quality of the brick.

GRANULATIONS.

There is a tendency for certain plastic clays to granulate in the grinding process. Instead of forming a dust-like powder, they roll up into shot-like grains. If the clay is mixed with water these granules may be destroyed. If, however the clay is used in the dry-press methods of molding, the granules are not destroyed in the process of molding and may cause an imperfect product. In the burning of the clay these granules may not unite unless the temperature of the brick is raised to the point of vitrification when the granules soften and unite. When the brick are not brought to this degree of temperature, incipient fusion of the outer side of the brick may cause a union of the granules, while the granules upon the inside are but indifferently united. The cross-breaking strength and the tensile strength of such a brick are very much impaired.

One remedy would be to insure absolutely dry conditions of the clay before grinding. Use a fine-mesh screen to eliminate larger granules, or mix thoroughly with a clay of lower fusibility.

SERRATIONS.

In the manufacture of stiff-mud brick the edges of the bars of clay are sometimes serrated as they come from the die. The serrations are caused by friction of the bar against the corners of the die. The same amount of friction may cause serrations in one clay and not in another. The bonding power of the latter is greater than that of the former. The friction between the bar and the clay may be partly overcome by the use of oil, steam or soap suds. Sometimes brick coming from the die contain serrations which are not very noticeable, but develop during drying. Repressing will in a large measure overcome serrations in brick.

BRITTLENESS.

Brittleness in brick is caused by too rapid cooling. After a kiln of hard brick is burned, it ought to be closed up and allowed to cool gradually. Gradual cooling toughens the brick and prevents brittleness. Clay conducts the heat so slowly that if the brick are cooled too rapidly internal stresses are set up which rupture them. Hard brick usually require from six to nine days for cooling. Wheeler thinks that far better results would be obtained by allowing twice that amount of time for cooling.

CHAPTER VIII.

GEOLOGY OF MISSISSIPPI CLAYS.

The following table shows the geological formations represented in the State, the oldest rocks being at the bottom and the youngest at the top.

GEOLOGICAL FORMATIONS OF MISSISSIPPI.

Cenozoic	Quaternary		Recent deposits.
			Columbia.
			Loess.
			Natchez.
			Lafayette.
	Tertiary	Miocene?—Grand Gulf.	
		Oligiocene—Vicksburg.	
		Eocene	Jackson.
			Claiborne.
			Wilcox.
			Midway.
Mesozoic	Cretaceous		Ripley.
			Selma chalk.
			Eutaw (Tombigbee).
			Tuscaloosa.
Paleozoic	Sub-carboniferous (Mississippian).		
	Devonian.		

PALEOZOIC.

DEVONIAN.

The oldest rocks of the State are of Devonian age. They form an outcrop along the western bank of the Tennessee River and along the lower courses of some of its small tributaries in Tishomingo County.

The rocks of these exposures consist of dark blue limestones with an over-burden of fossiliferous cherts and shales. The underlying rocks, as shown by well records, consist of limestones, sandstones and shales.

SUB-CARBONIFEROUS (MISSISSIPPIAN).

The rocks of the sub-carboniferous consist of limestones, cherts, shales and sandstones. They are of marine deposition and overlie the Devonian rocks. Exposures of the rocks are numerous along the courses of Big Bear Creek and other streams in the eastern part of Tishomingo and Itawamba Counties. In some places the chert layer has disintegrated into a very fine white silicious powder (tripoli) having the following composition:

TABLE 27.

ANALYSIS OF TRIPOLI FROM THE SUB-CARBONIFEROUS NEAR EASTPORT.

Constituent	*Per cent*
Moisture (H_2O)	0.20
Volatile matter (CO_2 etc.)	0.41
Silicon dioxide (SiO_2)	97.23
Iron oxide (Fe_2O_3)	0.60
Aluminum oxide (Al_2O_3)	0.30
Calcium oxide (CaO)	0.45
Magnesium oxide (MgO)	0.54
Sulphur trioxide (SO_3)	0.20
Total	99.93

Near Bear Creek, on the Candler place, a mine has been opened in tripoli, where the bed has a thickness of 15 or 20 feet. The over-burden consists of cherts with partings of tripoli. The mine is not now in operation.

The limestone which underlies the chert and outcrops in the bed of a creek at old Eastport is blue to gray in color and occurs in layers varying from 12 to 15 inches. The chemical properties are given in the analysis below.

TABLE 28.

ANALYSIS OF EASTPORT LIMESTONE.

Constituent	*Per cent*
Moisture (H_2O)	0.40
Volatile matter (CO_2 etc.)	5.06
Silicon dioxide (SiO_2)	43.18
Iron oxide (Fe_2O_3)	3.13
Aluminum oxide (Al_2O_3)	3.43
Calcium oxide (CaO)	39.47
Magnesium oxide (MgO)	3.19
Sulphur trioxide (SO_3)	2.23
Total	100.09

A sample of blue limestone belonging to the sub-carboniferous formation was taken from a ledge having a thickness of 6 feet at Cypress Pond near Mingo. This is a compact, hard blue limestone with a chemical composition as recorded below. It lies above the cherts mentioned above.

TABLE 29.

ANALYSIS OF CYPRESS POND LIMESTONE.

Constituent	*Per cent*
Moisture (H_2O)	1.10
Volatile matter (CO_2 etc.)	27.00
Silicon dioxide (SiO_2)	10.91
Iron oxide (Fe_2O_3)	5.00
Aluminum oxide (Al_2O_3)	8.71
Calcium oxide (CaO)	47.06
Magnesium oxide (MgO)	0.16
Sulphur trioxide (SO_3)	0.85
Total	100.25

At Mingo Bridge on Bear Creek the following section of sub-carboniferous rock are exposed:

1. Black shale containing lenticular masses of clay-stone .... 12 feet
2. Limestone containing a large number of fossils .. 5 "

The shale in No. 1 weathers into thin plates and the carbonate of iron is oxidized, producing a red coloration. The chemical composition is given below.

TABLE 30.

ANALYSIS OF MINGO SHALE.

Constituent	*Per cent*
Moisture (H_2O)	2.30
Volatile matter (CO_2 etc.)	13.30
Silicon dioxide (SiO_2)	54.46
Iron oxide (Fe_2O_3)	12.50
Aluminum oxide (Al_2O_3)	14.92
Calcium oxide (CaO)	2.56
Magnesium oxide (MgO)	0.00
Sulphur trioxide (SO_3)	0.85
Total	100.89

MESOZOIC.

CRETACEOUS.

Tuscaloosa.—The rocks of the Tuscaloosa formation in Mississippi consist of basal gravels, laminated clays and gray sands. Beds of lignite also occur in the formation. Many of the clays are white and

extremely aluminous in composition. Some of the clays are stained with an oxide of iron to such an extent as to form an ochre. The composition of a sample from R. F. Thorne's place, 6 miles north of Iuka, is given below:

TABLE 31.

ANALYSIS OF OCHEROUS CLAY FROM THE TUSCALOOSA, SIX MILES NORTH OF IUKA.

Constituent	*Per cent*
Moisture (H_2O)	0.87
Volatile matter (CO_2 etc.)	11.96
Silicon dioxide (SiO_2)	38.11
Iron oxide (Fe_2O_3)	11.73
Aluminum oxide (Al_2O_3)	36.42
Calcium oxide (CaO)	0.60
Magnesium oxide (MgO)	0.14
Sulphur trioxide (SO_3)	trace
Total	99.82

At Penniwinkle Hill, about 4 miles south of Iuka, the following geological section is exposed:

Section at Penniwinkle Hill.

	Feet
Blue micaceous clay weathering to yellow (top)	5
Gray, laminated, micaceous clay with thin ironstone layers	20
White, unlaminated but jointed clay	15

The first bed from the top probably forms a transition to the Lafayette which lies on the crest of the hill. The clay at the base is probably Tuscaloosa, though its determination is based entirely on stratigraphic conditions. The chemical composition of a sample of the clay from the white layer at the base is as follows:

TABLE 32.

ANALYSIS OF CLAY FROM PENNIWINKLE HILL.

Constituent	*Per cent*
Moisture (H_2O)	1.09
Volatile matter (CO_2 etc.)	7.34
Silicon dioxide (SiO_2)	68.65
Iron oxide (Fe_2O_3)	2.77
Aluminum oxide (Al_2O_3)	18.99
Calcium oxide (CaO)	.20
Magnesium oxide (MgO)	.20
Sulphur trioxide (SO_3)	trace
Total	99.24

PLATE XXII.

EUTAW SANDS ON TOMBIGBEE RIVER, COLUMBUS.

Some of the white clays of the Tuscaloosa formation contain a large quantity of tripoli from the subcarboniferous. Its white color and extreme fineness of grain conceal its presence from ordinary observation, but chemical determinations reveal it. The following table of analyses gives the chemical properties of a number of these clays:

TABLE 33.

ANALYSES OF TUSCALOOSA CLAYS FROM TISHOMINGO COUNTY.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5	*No.* 6	*No.* 7
Moisture (H_2O).......	.58	.58	.48	.59	1.18	.48	1.11
Volatile matter (CO_2)..	5.20	4.78	4.82	8.00	6.39	15.01	13.88
Silicon dioxide (SiO_2).	70.81	79.23	80.03	66.85	71.03	44.23	42.92
Iron oxide (Fe_2O_3)....	11.20	.67	1.68	3.77	.56	.81	.61
Aluminum oxide(Al_2O_3)	11.20	13.91	12.00	20.54	20.29	38.82	41.30
Calcium oxide (CaO)..	.60	.59	.26	.21	.20	.19	.37
Magnesium oxide(MgO)	.50	.21	.00	.18	.13	.13	.13
Sulphur trioxide(SO_3).	trace	trace	trace	trace	.25	.45	.18
Total............	100.09	99.97	99.27	100.14	99.98	100.12	100.57

Clay No. 1 is from the public road near the fish pond at Iuka. No. 2 is from the public road 2 miles south of Old Eastport. No. 3 is from the R. W. Peden farm, and No. 4 is from the Jas. Turner farm. Nos. 5, 6 and 7 were collected by Dr. F. T. Carmack from near Tishomingo city.

Eutaw (*Tombigbee*). -The Eutaw formation consists of greenish colored sands containing, in some localities, indurated layers of irregularly bedded sandstones, and in other places thin laminæ of clay. The sands are micaceous and contain some calcareous matter which increases in amount toward the upper horizon where it passes by a gradual transition into the overlying Selma chalk. The upper beds are abundantly fossiliferous. The lower beds are less fossiliferous and contain irregular masses of indurated materials and lenticular bodies of iron sulphide. Lignite and lignitic clays are not of infrequent occurrence in the lower beds.

Typical exposures of the fossiliferous strata are to be found along the bluffs of the Tombigbee River from Amory to Columbus. The river, sinking its channel into the soft rocks of the Eutaw, traces the western boundary of the formation across the northeastern part of the State. The Eutaw forms the chief water-bearing stratum for the northeastern prairie belt, and its collecting ground is along the Tombigbee River basin.

Selma Chalk (rotten limestone).—The rock of the Selma chalk is for the most part a fine-grained cretaceous limestone. On unweathered surfaces it has a bluish tint; on weathered areas it is white in color. Thin layers of crinoidal limestone and lenticular sandstone masses are occasionally encountered. Thin seams of asphaltum and nodular forms of iron pyrites occur in some outcrops. The amount of calcium carbonate in the formation varies, but in general it increases toward the southern portion of the area. The thickness also increases toward the south, being about 75 feet at the northern line of the State and reaching a thickness of about 1,000 feet near its southern limit.

The transition from the underlying arenaceous Eutaw to the highly calcareous Selma is gradual, so that the lowermost bed of the latter contains a large percentage of sand and a correspondingly small amount of calcium carbonate. Both vertically and horizontally the chalk varies in the amount of clay which it contains. In some places the formation contains as much as 16 per cent of alumina. The white rock, the weathered product of the blue, naturally contains more clay than the unweathered rock, since some of the calcium carbonate has been removed during the process of weathering and the insoluble aluminum silicate left behind.

TABLE 34.

ANALYSES OF SELMA CHALK.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5	*No.* 6
Moisture (H_2O)	1.10	.94	1.08	.40	1.50	2.75
Volatile matter (CO_2)	34.20	42.05	27.10	25.60	24.50	22.61
Silicon dioxide (SiO_2)	18.70	9.84	14.84	25.27	29.98	32.81
Iron oxide (Fe_2O_3)	6.00	2.58	4.50	10.35	5.60	4.65
Aluminum oxide (Al_2O_3)	.00	.19	15.59	4.81	5.45	11.15
Calcium oxide (CaO)	45.62	38.65	32.89	32.85	31.62	22.69
Magnesium oxide (MgO)	1.72	.18	.41	.84	.14	1.53
Sulphur trioxide (SO_3)	1.11	2.05	3.30	.32	.21	1.55
Total	98.45	96.48	99.71	100.64	99.02	99.74

Sample No. 1 is from Okolona, Chickasaw County; Nos. 2, 4 and 5 are from Oktibbeha County; No. 3 is from Tupelo, Lee County, and No. 6 is from West Point, Clay County. The majority of these samples contain clay, the per cent ranging from .48 to 39.44. They also contain some sand. The greater number of these samples were taken from the surface of the limestone where weathering processes have caused a considerable loss of calcium carbonate. Some unweathered

specimens of chalk have exhibited more than 90 per cent of lime. The weathering of the limestone has produced the main supply of brick clay of the Selma area.

Ripley.—Overlying the Selma chalk and bordering the northwestern portion of its outcrop are the marls of the Ripley. In some places the chief component of the marl is clay. They are generally highly fossiliferous and greenish in color, due to the presence of glauconite. In some exposures there are thinly bedded arenaceous limestones. The composition of one of these arenaceous rocks from Tippah County is given below.

TABLE 35.

ANALYSIS OF RIPLEY SANDSTONE.

Moisture (H_2O)	3.94
Volatile matter (CO_2)	1.82
Silicon dioxide (SiO_2)	82.95
Iron oxide (Fe_2O_3)	6.50
Aluminum oxide (Al_2O_3)	.87
Calcium oxide (CaO)	2.00
Magnesium oxide (MgO)	.54
Sulphur trioxide (SO_3)	.60
Total	99.22

Near the old mill in the northern part of the town of Ripley the following section is exposed:

Section of Ripley in the Town of Ripley.

	Feet
4. Yellow to brown loam	4
3. Gray clay	3
2. White shally rock	2
1. Fossiliferous green sand	10

The gray clay from No. 3 has the chemical composition recorded in the following analysis:

TABLE 36.

ANALYSIS OF CLAY, RIPLEY.

Moisture (H_2O)	8.23
Volatile matter (CO_2 etc.)	3.96
Silicon dioxide (SiO_2)	67.10
Iron oxide (Fe_2O_3)	6.60
Aluminum oxide (Al_2O_3)	10.96
Calcium oxide (CaO)	1.87
Magnesium oxide (MgO)	.54
Sulphur trioxide (SO_3)	.51
Total	99.77

CENOZOIC.

TERTIARY.

Eocene.

The eocene of Mississippi is composed of the following stages: Midway, Wilcox, Claiborne and Jackson.

Midway.—The Midway is composed of two formations, the Clayton limestones and the Porter's Creek (Flatwoods) clays. The latter are gray laminated and somewhat shaly clays. Some of the lowermost beds contain small white concretions of irregular shape and usually of small size. In the upper beds, layers of ironstone concretions abound. These are usually lens-shaped masses; some are irregular in form. Occasionally the lens-like masses form a continuous layer which persists for several rods. The clay is frequently micaceous. It is exceedingly fine-grained and highly silicious, containing as much as 70 per cent of silicon dioxide. The Flatwoods clay is exceedingly sticky and the wagon roads across its outcrop are kept in condition with great difficulty. Though of highly silicious character, the grains of silica are exceedingly small so that they are not detected by ordinary methods of observation.

The following table shows the analyses of some samples of the Flatwoods clays:

TABLE 37.

ANALYSES OF FLATWOOD CLAYS.

	No. 1	*No.* 2	*No.* 3	*No.* 4
Moisture (H_2O)	2.97	4.50	5.65	4.95
Volatile matter (CO_2 etc.)	3.91	7.77	5.04	9.05
Silicon dioxide (SiO_2)	75.60	61.62	71.47	65.60
Iron oxide (Fe_2O_3)	8.24	15.29	6.97	7.20
Aluminum oxide (Al_2O_3)	7.00	.87	9.45	10.50
Calcium oxide (CaO)	1.20	.81	.40	1.12
Magnesium oxide (MgO)	.67	.69	.63	.60
Total	99.84	99.83	99.74	99.98

Clays Nos. 1 and 4 are from Oktibbeha County; No. 2 is from Winston County, and No. 3 is from Noxubee County.

Wilcox (*Lagrange*).—The Wilcox formation consists of sands and clays with intercalated beds of lignite. The sands are for the most part unconsolidated sediments, though occasionally irregular masses of sandstone or ironstone appear in the outcrops of its strata. The

sands are very much cross-bedded and inter-bedded with thin seams of clay. The colors are variegated. In many places, thick beds of pink or white pottery clays are present.

In the upper portion of the formation there are beds of shale-like clay of a dark color. The clays have a low specific gravity and are fine in grain.

There is an outcrop of these clays in the bank of the Yalobusha River, at Grenada. The bed has a thickness of about 40 feet. The chemical composition of a sample of the clay is given below:

TABLE 38.

ANALYSIS OF WILCOX CLAY, GRENADA.

Moisture (H_2O)	5.91
Volatile matter (CO_2)	8.75
Silicon dioxide (SiO_2)	61.80
Iron oxide (Fe_2O_3)	3.88
Aluminum oxide (Al_2O_3)	16.50
Calcium oxide (CaO)	1.00
Magnesium oxide (MgO)	.23
Sulphur trioxide (SO_3)	.19
Total	98.26

The pink and the white clays of the lower and middle horizons of the Wilcox are used in a number of counties in the manufacture of stoneware. The following table gives the analyses of some of the pottery clays:

TABLE 39.

ANALYSES OF WILCOX POTTERY CLAYS.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5	*No.* 6
Moisture (H_2O)	.66	1.84	1.92	.62	.23	1.47
Volatile matter (CO_2 etc.)	7.25	8.23	7.66	7.02	4.81	9.24
Silicon dioxide (SiO_2)	62.41	60.78	63.56	64.86	75.78	59.82
Iron oxide (Fe_2O_3)	2.80	3.52	2.83	4.19	3.56	1.26
Aluminum oxide (Al_2O_3)	24.02	24.12	21.92	20.70	14.11	27.19
Calcium oxide (CaO)	.57	.73	.48	.69	.54	.49
Magnesium oxide (MgO)	.50	.38	.62	.59	.52	.37
Sulphur trioxide (SO_3)	.56	.38	.28	trace	.00	.31
Total	98.97	99.98	99.29	98.67	99.55	100.15

Clays Nos. 1, 2 and 3 are from Marshall County; Nos. 4 and 5 are from Lafayette County; No. 6 is from Webster County.

Claiborne.—The rocks of the Claiborne are divided into Tallahatta buhrstone (Siliceous Claiborne), Lisbon, and the undifferentiated Claiborne.

The Tallahatta buhrstone is composed of hard white quartz rocks with impure calcareous sandstones and claystones. In some localities the formation consists of ferruginous sands, but slightly cemented and containing numerous fossils. In other localities the sandstones are cherty in character, with thin layers inter-bedded with sandy clays. The white quartz rock constitutes one of our best road metals. Unfortunately very little of it has been used in this State. During 1906, 100 carloads were shipped from West to Louisiana to be used in street pavement work.

The Lisbon is composed of white sands containing calcareous material, greenish marls, and lignitic clays. The calcareous beds are highly fossiliferous. Species of the genera Ostrea and Pecten are the most abundant fossils. Between the Lisbon beds and the Jackson formation is a great thickness of undifferentiated Claiborne.

Jackson.—The Jackson formation is composed of clays, marls and sands. The clays in some outcrops contain the bones of Zeuglodon, an extinct marine animal of huge size. Aggregates of selenite crystals are abundant in some layers. The marls are very generally fossiliferous. The sands are sometimes interbedded with lignitic clays or lignite.

The outcrop of the Jackson and the Vicksburg forms the central prairie belt of the State.

At Morton, there is an exposure of the upper Jackson beds which has the following stratigraphy:

Section of Upper Jackson Beds at Morton.

	Feet
5. Grayish clay in thin layers	5
4. Lignite and lignitic clay	6
3. White sand with clay partings	15

And at a lower level:

	Feet
2. Layers of yellow sand and gray clay	20
1. Gray clay	6

On the south side of the ridge where the above-mentioned exposure occurs, the following section is exposed:

3. Orange sand with gravel and ironstone (Lafayette).
2. Clay with purple clay stones (Grand Gulf?).
1. Gray laminated clay with selenite crystals (Jackson).

At Barnett, a yellow laminated clay streaked with blue has a thickness of at least 25 feet. The clay contains crystals of selenite and fossils. It has the following chemical properties:

TABLE 40.

ANALYSIS OF BARNETT CLAY.

Moisture (H_2O)	5.55
Volatile matter (CO_2 etc.)	13.80
Silicon dioxide (SiO_2)	38.75
Aluminum oxide (Al_2O_3)	22.83
Iron oxide (Fe_2O_3)	3.14
Calcium oxide (CaO)	14.25
Magnesium oxide (MgO)	1.01
Sulphur trioxide (SO_3)	trace
Total	99.33

Oligocene.

Vicksburg.—The line of outcrop of the Vicksburg parallels the Jackson on the South. Its rocks are limestones and marls. Typical exposures occur in the bluffs of the river at Vicksburg. In the exposures along the river front, there are five or six layers of limestone interbedded with marl and clay. They overlie dark colored clays and sands. The limestone varies in thickness in the different ledges and even in the same ledge. The individual layers are from 1 to 6 feet thick. The following table gives the chemical composition of Vicksburg limestone from a number of exposures:

TABLE 41.

ANALYSES OF VICKSBURG LIMESTONE.

	No. 1	*No.* 2	*No* 3	*No.* 4
Moisture (H_2O)	.40	1.00	1.79	2.10
Volatile matter (CO_2 etc.)	37.22	35.20	35.40	33.16
Silicon dioxide (SiO_2)	7.08	7.31	6.77	14.88
Iron oxide (Fe_2O_3)	2.50	4.00	2.00	3.59
Aluminum oxide (Al_2O_3)	.61	13.66	4.68	5.70
Calcium oxide (CaO)	50.44	36.62	45.51	36.86
Magnesium oxide (MgO)	1.07	.29	.64	.99
Sulphur trioxide (SO_3)	.38	2.78	3.00	.24
Total	99.70	100.86	99.79	97.72

Sample No. 1 is from Warren County; No. 2 and No. 3 are from Wayne County, and No. 4 is from Rankin County.

At Brandon, in Rankin County, there are some excellent exposures of Vicksburg limestone. On the Robinson place, 4 miles southeast

of Brandon, there is a stone quarry in which six layers of limestone are found interbedded with marl in the following stratigraphic order:

Section of Vicksburg at Robinson Quarry, near Brandon.

	Feet
13. Soil and decomposed rock	2
12. Limestone	1–1½
11. Marl	1
10. Limestone	2
9. Marl	2
8. Limestone	1¼
7. Marl	1½
6. Limestone	1½–2
5. Marl	2
4. Limestone	2
3. Marl	1¼
2. Limestone	2
1. Marl	2

The limestone is bluish on fresh fractures but weathers white. It is fossiliferous, containing abundant evidence of marine life.

Miocene.

Grand Gulf.—In Mississippi, the Grand Gulf formation is made up of gray, clayey sandstones, white quartz rocks and clays. The latter contain considerable organic matter and are of a dark color in many areas. The Pascagoula is thought by some to be a part of the Grand Gulf. Samples of silicious claystones of the Grand Gulf have been analyzed with the following results:

TABLE 42.

ANALYSES OF GRAND GULF CLAYSTONES.

	Per cent			
	No. 1	*No.* 2	*No.* 3	*No.* 4
Moisture (H_2O)	3.59	.74	.75	.50
Volatile matter (CO_2 etc.)	2.93	1.51	3.50	.38
Silicon dioxide (SiO_2)	77.44	92.13	81.85	88.11
Iron oxide (Fe_2O_3)	4.17	1.61	3.00	4.00
Aluminum oxide (Al_2O_3)	11.09	2.96	8.32	5.81
Calcium oxide (CaO)	.53	.54	.82	.56
Magnesium oxide (MgO)	.31	.42	.00	.00
Sulphur trioxide (SO_3)	.05	.05	2.84	1.50
Total	100.11	99.96	101.08	100.86

Some beds of the Grand Gulf formation are composed of clear quartz grains cemented together with a silicious cement so that they present the appearance and hardness of quartzites. White chalk-like clays occur in some localities.

PLATE XXIII.

A. DENUDATION IN LAFAYETTE AFTER DEFORESTING, BRANDON.

B. SOFT-MUD BRICK HACKED UNDERED COVER SHED.

The table given below contains the analyses of some of the Grand Gulf clays:

TABLE 43.

ANALYSES OF GRAND GULF CLAYS.

	No. 1	*No.* 2	*No.* 3	*No.* 4
Moisture (H_2O)	.60	2.36	3.65	1.09
Volatile matter (CO_2 etc.)	5.10	4.01	1.16	2.98
Silicon dioxide (SiO_2)	72.32	74.92	68.28	82.42
Iron oxide (Fe_2O_3)	3.00	2.96	10.00	2.40
Aluminum oxide (Al_2O_3)	15.81	13.25	1.76	9.65
Calcium oxide (CaO)	.47	.20	.87	.70
Magnesium oxide (MgO)	trace	.38	.76	.46
Sulphur trioxide (SO_3)	2.75	2.12	4.26	.12
Total	100.05	100.20	90.14	99.62

Nos. 1, 2 and 4 are from Jefferson County and No. 3 is from Warren County.

QUATERNARY.

Lafayette.—The rocks of the Lafayette consist of sands, gravels, conglomerates, ironstones, loams and plastic clays. It is one of the most widely distributed formations in the State occupying practically all of the surface of the higher lands. Bright coloring is characteristic of nearly every outcrop. Orange, purple, pink, yellow, buff and white colored sands and clays occur in a great diversity of stratigraphic relationships. Blotched and mottled surfaces abruptly changing from one color to another are common. The prevailing coloration is largely due to the presence of ferric iron.

The thickness of the formation rarely exceeds 50 feet. The stratigraphic appearance of many of the sands is so suggestive of dune deposition that the conclusion that they are of eolian origin would seem irresistible but for the presence of "pebble" clay. The shape, mass, and distribution of this is not in harmony with such a view.

Three modes of origin have been suggested for the Lafayette. First, the glacio-fluvial hypothesis suggested by Hilgard in a Report on the Agriculture and Geology of Mississippi, published in 1860. Second, the marine deposition hypothesis, published by McGee in Twelfth Annual Report of the United States Geological Survey. Third, the Aggradation hypothesis, suggested by Chamberlin and Salisbury in Earth History, Vol. III, pp. 305–307. The statement of the last hypothesis is given in the words of the authors: "As here interpreted, the Lafayette formation belongs to an important class,

long neglected, but now coming into recognition, whose distinctive features are less critically familiar than those of marine, lacustrine, and typical fluvatile formations. The preferred interpretation is as follows: After the Cretaceous base-leveling of the region, the Appalachian tract was bowed up and a new stage of degradation inaugurated. During the long Eocene period, a partial peneplaining of the less resistant tracts was accomplished. This was slightly interrupted by the Oligiocene deformation, and the streams mildly rejuvenated in the more responsive tracts. During the Miocene period, base-leveling was resumed, abetted by relative subsidence along shore, as indicated by the landward spread of the Miocene sea, and the open low grade valleys and abundant low cols of the region west of the Appalachians, if the interpretation here given be correct. At the opening of the Pliocene, therefore, the Appalachian tract is supposed to have been affected by broad, flat, intermontane valleys, mantled by a deep layer of residual decomposition products. The Piedmont tract skirting the Appalachians is supposed to have been flanked on the seaward side by a peneplain near sea level, and on the other side by broad, open valleys of low gradient. It is assumed that the upward bowing was felt first in a relatively narrow belt along the predetermined axis, that the rise was gradual, and that the rising arch increased its breadth as it rose. The first bowing along the axis rejuvenated the head waters of the streams which reached it, and the surface, deeply mantled with residuum accumulated during the peneplaining stage, readily furnished load to the streams in flood stages. When the streams reached that portion of the peneplain not yet affected by the bowing, they found themselves loaded beyond their competency, and gave up part of their load. Thus arose a zone of deposition along the bowed tract, with continued rise, the mountainward border of the depositional zone is supposed to have been shifted seaward, and the previous border elevated and subjected to erosion, while the material removed was re-deposited in a new zone farther from the axis of rise.

"Thus the process is presumed to have continued till the border of the lifted tract passed beyond the present seacoast, after which the whole mantle was subjected to erosion, which has reached a notable degree of advancement before the first known glacio-fluvial deposits were laid down."

Plate XXIV.

SODDING LOESS SLOPES WITH BERMUDA GRASS AS A PROTECTION AGAINST EROSION, NATIONAL PARK, VICKSBURG.

Natchez.—The Natchez formation has its typical development at Natchez, where the thickness assigned is 200 feet. It rests erosively unconformable upon the Lafayette. The formation is composed of sands and gravels containing calcareous clays. According to Chamberlin, its age is either sub-Aftonian or Aftonian. (See Earth History, Vol. III, pp. 386–8.)

Loess (*Bluff Formation*).—A fine silty material of brownish color containing concretions and tubules of lime carbonate and shells of species of gastropods is called the Loess. In thickness, it varies from a few feet to a hundred or more.

The Loess is thought to be a deposit formed largely by winds, which transported silt and rock flour from the flood plains of rivers and from over-washed plains during glacial or inter-glacial epochs.

In Mississippi the Loess occupies a tract along the eastern border of the Mississippi Valley. The tract is narrow and the thickest part of the deposit is upon the immediate banks of the valley and thins rapidly toward the east. In the majority of places the upper surface is occupied by a bed of residual clay, having a thickness of 6 to 10 feet, and much used for brick clay.

Columbia.—The brown and yellow loams which occupy the surface of practically all the hill country of the State have been assigned to the Columbia. In point of time these loams represent in some instances doubtless all of the time which has elapsed since the Lafayette deposition. In other instances only that time which has elapsed since the deposition of the Loess.

The time which has elapsed since the deposition of the Lafayette has permitted the accumulation of various surficial deposits of clay, sand and loam. These have resulted in a large measure from the disintegration and decomposition of older formations. That the formation is largely residual is not to be denied. That it is composed partly of transported material is within the bounds of reasonable probability. That such transported material is largely of Eolian origin is also very probable.

The brown loam and clay which rest upon the Loess is without doubt a residual product of the latter's decomposition. It is probable that the loams are for the most part only modified forms of the Loess. The Loess thins out and loses its identity a short distance from the

Mississippi bluffs. The loams, however, cover the whole State except where they have been removed by erosion.

Recent Deposits.—The recent deposits consist of undifferentiated loams of the hill country, the alluvial deposits of the flood plains, and recent deposits along the coast, some of which are marine, others lacustrine and others estuarine.

The largest area of recent deposits is that of the Yazoo basin. This basin is a flood plain area between the Yazoo River and the Mississippi River. The rocks, sands, clays and silts have been deposited by the streams.

The flood plain material is of two kinds. First, the sandy loam which is found along the courses of the streams. Following the law of deposition, when a stream carrying sediment overflows its banks the water begins to lose its velocity and to deposit the coarser, heavier particles of its suspended matter near the streams. Second, the finer clayey materials which are found on the inter-stream areas. According to the same law of deposition, the finer particles are carried longer in suspension and are dropped farther from the main channel. Frequently coarse sediments are carried into the inter-stream areas by temporary currents set up during overflows. Therefore, layers of sandy loam are often interbedded with layers of plastic clay.

CHAPTER IX.

THE CLAYS AND CLAY INDUSTRIES OF NORTHERN MISSISSIPPI BY COUNTIES.

The following chapter contains a statement of our present knowledge of the clays and clay industries of the northern half of the State. The report is not complete and is only preliminary. The clay industries, like all other industries in the State, are developing so rapidly that the collector of statistics scarcely turns his back upon a field before new plants have sprung into existence. The following is a list of the counties wholly or partly included in the report:

Alcorn	Holmes	Monroe	Tate
Attala	Kemper	Newton	Tippah
Carroll	Lafayette	Noxubee	Tunica
Clay	Lauderdale	Oktibbeha	Union
Chickasaw	Lee	Panola	Warren
Choctaw	Leflore	Pontotoc	Washington
Coahoma	Lowndes	Prentiss	Webster
De Soto	Madison	Rankin	Winston
Grenada	Marshall	Scott	Yalobusha
Hinds	Montgomery	Sunflower	Yazoo

ALCORN COUNTY.

GEOLOGY.

The bed-rock of this county is formed of Cretaceous strata. The extreme southeastern corner of the county is underlain by the Tuscaloosa sands and clays. The eastern part of the county is underlain by the sands of the Eutaw (Tombigbee) group. The central portion of the county has for its subformation the Selma chalk, and the western portion is occupied by the Ripley. The principal mantle rock formations are the Lafayette sands and clays and the Columbia loams. There are also some residual deposits formed directly from the bed-

rock formations. The Lafayette formation is represented by isolated outcrops. The Columbia loam has a wider distribution. In the Selma chalk area the soil often rests directly upon the chalk.

CLAY INDUSTRY.

Corinth.—The residual clay from the Selma is utilized in the county in the manufacture of brick. Lafayette sandy clay and the Columbia loams are used with the residual Selma, since the latter is generally too plastic. At Corinth, the residual clay of the Selma chalk and the Lafayette clay are used in the manufacture of brick by the Corinth Brick Manufacturing Co. In the pit the following stratigraphical conditions are revealed:

Section of the Pit of the Corinth Brick Mfg. Co., Corinth.

	Feet
4. Yellowish loam (Columbia)	3
3. Red sandy clay (Lafayette)	4
2. Plastic clay (residual Selma)	2–3
1. White chalk (Selma)	...

In the manufacture of brick a mixture of Nos. 2, 3 and 4 is used. The clay is prepared in a granulator and tempered in a pug mill. It is molded in a stiff-mud, end-cut machine. The brick are burned in rectangular, up-draft kilns of the clamp type.

A sample of clay taken from layer No. 2, upon analysis, gave the following results:

TABLE 44.

ANALYSIS OF RESIDUAL SELMA CLAY, CORINTH.

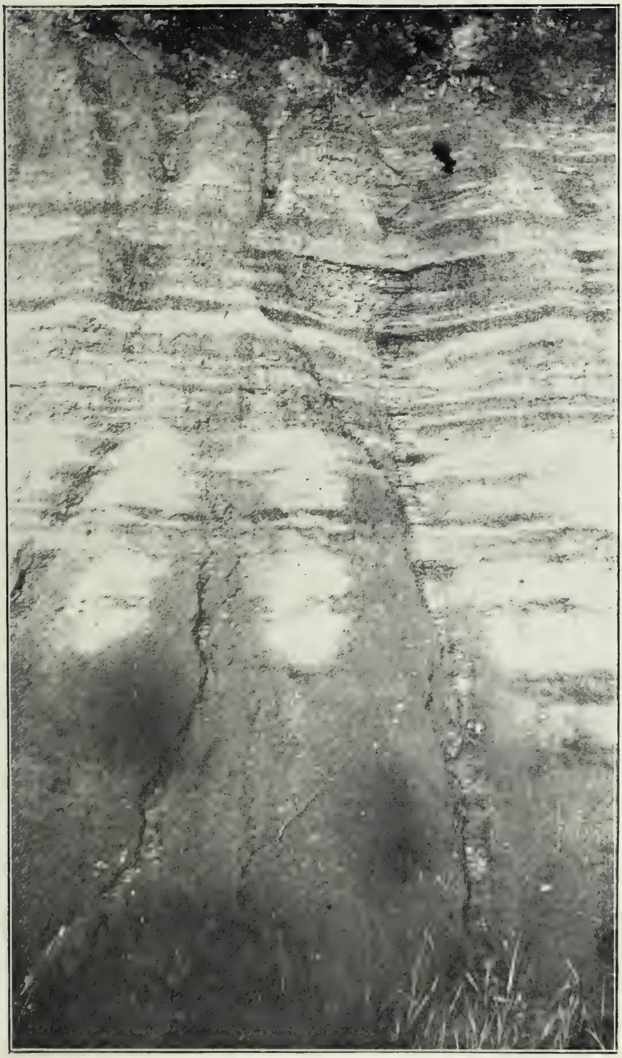
	No. 104
Moisture (H_2O)	3.85
Volatile matter (CO_2)	4.45
Silicon dioxide (SiO_2)	76.77
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	8.56
Calcium oxide (CaO)	.31
Magnesium oxide (MgO)	.04
Sulphur trioxide (SO_3)	.00
Total	100.23

RATIONAL ANALYSIS.

Clay substance	21.65
Free silica	66.72
Impurities	6.60

A sample of the Selma chalk collected from this locality by A. F. Crider has the following chemical composition:

PLATE XXV.



OUTCROP OF BUHRSTONE SHALE-CLAY, VAIDEN.

TABLE 45.

ANALYSIS OF SELMA LIMESTONE, CORINTH.

Moisture (H_2O)	4.47
Volatile matter (CO_2 etc.)	23.70
Silicon dioxide (SiO_2)	25.40
Aluminum oxide (Al_2O_3)	6.88
Iron oxide (Fe_2O_3)	8.62
Calcium oxide (CaO)	26.37
Magnesium oxide (MgO)	.58
Sulphur trioxide (SO_3)	.64
Total	96.66

Clay from layer No. 2 of the above section contains 17.40 per cent of clay and some silica. It cannot be used alone in the manufacture of brick. The chief objections to its use are : (*a*) the large amount of soluble salts which it contains; (*b*) an excess of calcium carbonate; (*c*) high plasticity. The soluble salts are liable to produce kiln-white or wall-white, and calcium carbonate is liable to cause cracking of the ware, and the high plasticity may prevent successful drying except by extremely slow methods.

A sample of clay from layer No. 3 has the following physical properties: It requires 19 per cent of water to render it plastic. The tensile strength of its raw brickettes is 87 pounds per square inch; when burned it has a tensile strength of 150 pounds per square inch. The color of the burned brickettes is a deep red. The total shrinkage is only 2 per cent. The clay slakes very rapidly. This clay lacks sufficient plasticity for the stiff-mud process of molding. In connection with No. 4 it could be utilized in the manufacture of soft-mud brick.

No. 4 is a loam which is lacking in plasticity. It does not possess high enough bonding power to make good brick. A mixture of these three layers in the proper proportion is essential to a good stiff-mud product. To obtain the best results the clays should be crushed and thoroughly mixed before going to the molding machine. In case a large amount of clay from No. 2 is used, the brick ought to be carefully guarded from air currents for the first few hours after being taken from the machine.

Rienzi.—In 1906, Mr. J. D. Furtick of Rienzi was engaged in the manufacture of brick for local use. The brick were molded by the

soft-mud process and burned in rectangular, up-draft scove kilns. The pit from which the clay was taken has the following stratigraphy:

Section of Clay Pit, Rienzi.

	Feet
4. Soil	1
3. White "hard pan" fine sand	1
2. Yellowish clay (Columbia?)	10
1. Water bearing sand	...

Layer No. 2 is light gray in the upper portion and bluish in color in the lower portion. The grayish clay has a total shrinkage of 5 per cent. Its tensile strength in the raw state is 182 pounds. Hard-burned brickettes have a strength of 322 pounds. It requires 27 per cent of water to render it plastic. In passing from the stiff-mud to the burnt state it loses 33 per cent of its weight. The burned brickettes absorb 14.92 per cent of water. The white clay absorbs 26.66 per cent of water. A sample of No. 3 required 16 per cent of water to render it plastic. It has a total shrinkage of 2 per cent. In the raw state its tensile strength is only 45 pounds per square inch, and when burned only 30 pounds per square inch. It is composed of very fine silica, and lacks bonding power.

ATTALA COUNTY.

GEOLOGY.

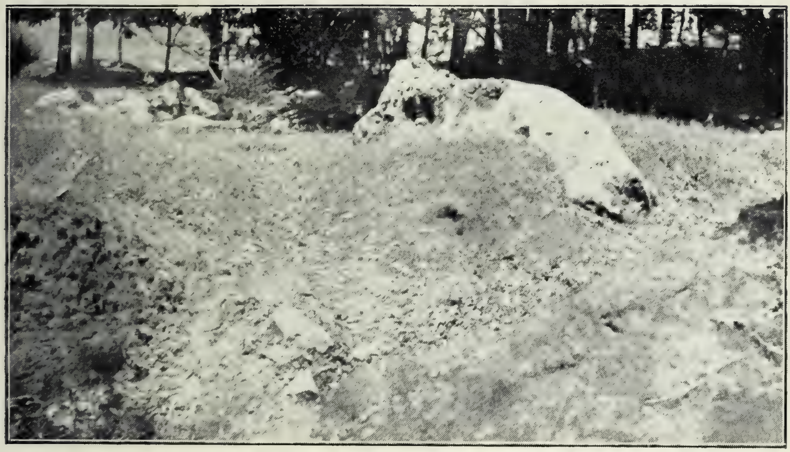
Attala County lies partly within the Wilcox, but almost wholly within the Claiborne area. The surface formations are of Lafayette and Columbia age.

CLAY INDUSTRY.

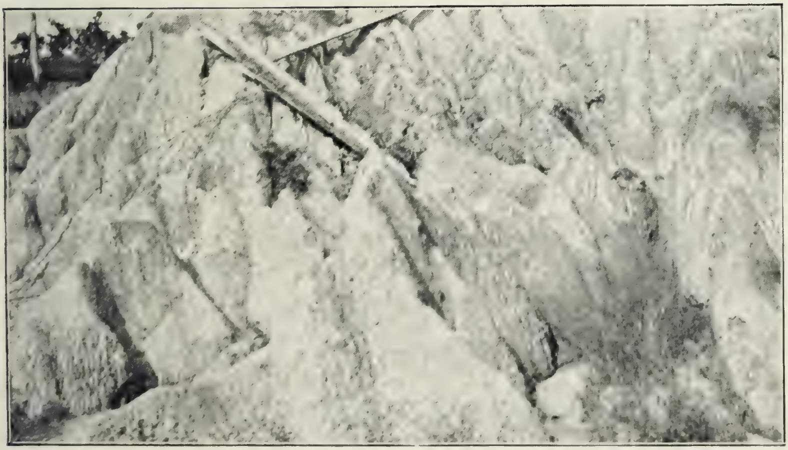
Kosciusko.—The clay from the Columbia is used at Kosciusko in the manufacture of brick, in a plant operated by Storer and Miller. The plant was first established by A. M. Storer in 1902, and in 1906 the Storer and Miller Company was formed. The clay is tempered in a pug mill and molded in an end-cut stiff-mud machine. The kilns are up-draft clamp kilns of rectangular shape. The brick are dried on pallets in open covered racks.

The second bottom clays of the surface formations are, generally speaking, the best clays for the manufacture of stiff-mud brick. The Lafayette and Columbia loams of the higher lands may be used in the manufacture of soft-mud brick. The aluminous clays of the

Plate XXVI.



A. QUARTZ BOWLDERS OF THE BUHRSTONE, NEAR WEST.



B. EROSION IN THE LAFAYETTE, VAIDEN.

Wilcox may be utilized in the manufacture of a light colored, dry-pressed brick. The white color can be varied by sprinkling the surface of the brick with iron or manganese to produce specks or spots in burning. These spotted brick make a very attractive ware.

CARROLL COUNTY.

GEOLOGY.

The strata of the Tallahatta buhrstone constitute the bed-rock of Carroll County. The rocks consist of clays, sands and quartzites. The clays are exposed in cuts and along the banks of the streams; the quartzites form the cap-rock for some of the inter-stream areas.

The mantle rock formations of the county are Lafayette, Loess, Columbia loam, and the alluvium of the Yazoo basin. In a railroad cut on the Illinois Central, south of the station at Vaiden, there are exposed about 30 feet of laminated clay belonging to the Claiborne. This clay is of a brownish-gray color, varying to purple and weathering to red or purple. The clay is interbedded with layers of very sandy white clay. It also contains thin wavy partings of limonite. In a small depression on the west side of the cut, a bad-land type of topography has been developed, and the following stratigraphic features are revealed:

Section near Vaiden.

	Feet
5. Soil	1
4. Brown loam	8
3. Reddish clay	10
2. Red and white mottled clay	10
1. Grayish clay	5

The reddish clay of No. 3 is probably Lafayette, though it has no gravel and is very similar to the residual clay of No. 1. The line of separation of No. 3 and No. 4 is more clearly marked by change in texture than by change in color. Wherever No. 4 has been completely removed by erosion, the exposed surface of No. 3 cracks into blocks of circular shapes. This is due to the high plasticity and excessive shrinkage of the clay. In some places No. 3 contains small flat ironstone concretions.

The clay from No. 1 requires 27 per cent of water for plasticity. It has a total shrinkage of 15 per cent. The raw clay brickettes

have a tensile strength of 187 pounds per square inch. When burned, the tensile strength is 200 pounds per square inch. Absorption is 14.63 per cent. The chemical composition of a sample of No. 1 is given below as analysis No. 83:

TABLE 46.

ANALYSIS OF RESIDUAL CLAY, VAIDEN.

	No. 83
Moisture (H_2O)	10.06
Volatile matter (CO_2 etc.)	7.00
Silicon dioxide (SiO_2)	59.22
Iron oxide (Fe_2O_3)	4.70
Aluminum oxide (Al_2O_3)	10.30
Calcium oxide (CaO)	1.68
Magnesium oxide (MgO)	1.18
Sulphur trioxide (SO_3)	.23
Total	94.37

RATIONAL ANALYSIS.

Clay substance	26.06
Free silica	15.76
Impurities	7.89

The red residual clay, No. 2, of the section given above, has the following composition:

TABLE 47.

ANALYSIS OF RESIDUAL CLAY, VAIDEN.

	No. 84
Moisture (H_2O)	6.77
Volatile matter (CO_2 etc.)	6.75
Silicon dioxide (SiO_2)	66.06
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	9.47
Calcium oxide (CaO)	1.95
Magnesium oxide (MgO)	.72
Sulphur trioxide (SO_3)	.10
Total	97.87

RATIONAL ANALYSIS.

Clay substance	23.96
Free silica	51.58
Impurities	9.02

This clay has too high a shrinkage to be utilized without the aid of non-plastic material. It would also require thorough crushing before it could be used, as it slakes slowly. The non-plastic material of the Lafayette or Columbia near at hand could be used to dilute it.

PLATE XXVII.

UP-DRAFT CLAMP KILNS, END VIEW, WEST POINT.

CLAY COUNTY.

GEOLOGY.

The bed-rock of Clay County belongs to the Cretaceous and the Eocene periods. The eastern part of the county is underlain by the Eutaw (Tombigbee) formation; the central portion by the Selma chalk, and the western part by the Porter's Creek (Flatwoods). The mantle rock formations are the Lafayette and the Columbia. The Lafayette occurs only in isolated areas. The Columbia has a much larger distribution, but there are areas in which the soil rests directly upon the surface of the Selma without intervening mantle rock. Much of the surface clay has been formed by the decomposition of the Selma chalk.

CLAY INDUSTRY.

West Point.—In the pit belonging to the West Point Manufacturing Company, at West Point, the clay rests upon a stratum of the Selma chalk. On weathered surfaces the chalk is white, but unweathered surfaces are blue. The chalk at this point is very fossiliferous, containing many specimens of the genus Inoceramus.

The limestone immediately underlying the clay contains sufficient clay to render it plastic. When molded into brickettes it is white or blue, depending on whether the weathered or unweathered chalk is taken. The burned clay has a white or light yellow color. The brickettes have a tensile strength of 152 pounds per square inch in the unburned state. Its air shrinkage is about 6 per cent. Samples of this limestone and the overlying clay have the following composition:

TABLE 48.

ANALYSES OF SELMA LIMESTONE AND RESIDUAL CLAY, WEST POINT.

	No. 32	*No.* 33
Moisture (H_2O)	4.25	2.75
Volatile matter (CO_2 etc.)	7.77	22.61
Silicon dioxide (SiO_2)	73.70	32.81
Iron oxide (Fe_2O_3)	11.14	4.65
Aluminum oxide (Al_2O_3)	3.81	11.15
Calcium oxide (CaO)	1.04	22.69
Magnesium oxide (MgO)	.00	1.53
Sulphur trioxide (SO_3)	.21	1.55
Total	99.97	99.74

No. 32. Residual clay.
No. 33. Selma limestone.

The above mentioned limestone contains 28.20 per cent of clay and a small per cent of free silica. Doubtless the low percentage of calcium carbonate is due to the solvent action of circulating waters which dissolved out and carried away much of this soluble constituent and produced a concentration of such insolubles as clay and silica. As the distance from the limestone to the top of the clay deposit increases, there is a corresponding decrease in the amount of calcium carbonate. On the other hand, the amount of silica increases to the top while the amount of alumina increases to a certain point, and then decreases as the amount of free silica increases.

The clay immediately overlying the limestone contains a high per cent of calcium carbonate in some places. In burning, the calcium compound is calcined and when the bricks absorb moisture the lime slakes and produces heat. The heat and the swelling of the lime cause the brick to crack open. This would not occur if the lime was thoroughly mixed throughout the clay in small particles. The clay contains soluble salts, which produce efflorescence on the brick in drying. The principal salt is calcium sulphate, formed by the decomposition of pyrite in the presence of calcium carbonate. This salt is brought to the surface by the water which comes from the brick during drying, and forms a white coating on the surface. The bottom clay is so plastic that it gives trouble in drying when used alone. The best results are to be obtained by not taking the clay too close to the limestone; and by mixing the lower clay with the clay from the more non-plastic layer. Other non-plastic materials, such as sand and cinders, may be used to facilitate the drying of the clay; but by the use of the top clay the loss of bonding power is not so greatly diminished. This clay was used several years ago by Mr. John Mahafa in the manufacture of drain tile. It is stated that the lack of demand for tile at that time caused the enterprise to be abandoned.

On comparing the analysis of No. 32 with that of No. 33 an increase in silica from the limestone to the clay of nearly double may be noted. The lime element, however, has decreased 18.94 per cent.

Clay No. 32 has a total shrinkage of 10 per cent. It loses 42 per cent in weight in drying and burning. The burned brickettes are pale yellow due to the presence of lime which destroys the coloring effects of the iron. The average tensile strength of 12 unburned brickettes was 152 pounds per square inch. The minimum strength was 122

Plate XXVIII.

TAKING BRICK FROM OFF-BEARING BELT OF AN END-CUT MACHINE.

pounds and the maximum 172 pounds. It has an absorption of 16.86 per cent. When mixed with 10 per cent of cinders and burned, it has an absorption of 14.28 per cent; when mixed with 10 per cent of coal, it has an absorption of 12.72 per cent.

The clay at the top of the pit has suffered a still greater loss in soluble constituents and shows an increase in insoluble elements. The following analysis shows its composition:

TABLE 49.

ANALYSIS OF SURFACE CLAY, WEST POINT.

	No. 34
Moisture (H_2O)	2.41
Volatile matter (CO_2 etc.)	7.66
Silicon dioxide (SiO_2)	73.70
Iron oxide (Fe_2O_3)	11.14
Aluminum oxide (Al_2O_3)	3.81
Calcium oxide (CaO)	1.04
Magnesium oxide (MgO)	.00
Sulphur trioxide (SO_3)	.21
Total	99.97

RATIONAL ANALYSIS.

Clay substance	9.63
Free silica	69.22
Impurities	12.34

This clay probably contains a mixture of Lafayette sand and Columbia loam, both of which have been washed down from a neighboring elevation. The amount of impurities exceeds the amount of clay. The large per cent of free silica renders the clay non-plastic. However, it supplies non-plastic material which may be used for diluting the more plastic clay below.

The Welch-Trotter Brick Manufacturing Company operates a yard on the line of the Illinois Central Railroad at West Point about ½ mile south of the station. The plant was established in 1905. The clay used is mostly residual clay from the Selma chalk, though the upper portion may be in part Columbia loam. The pit has been opened to a depth of 7 to 8 feet. The lower clay is very plastic. A sample of clay analyzed from near the bottom of the pit gave the following results:

TABLE 50.

ANALYSIS OF CLAY USED AT THE WELCH-TROTTER BRICK PLANT, WEST POINT.

	No. 44
Moisture (H_2O)	3.45
Volatile matter (CO_2 etc.)	5.58
Silicon dioxide (SiO_2)	72.32
Iron oxide (Fe_2O_3)	7.44
Aluminum oxide (Al_2O_3)	8.74
Calcium oxide (CaO)	1.55
Magnesium oxide (MgO)	.47
Sulphur trioxide (SO_3)	.51
Total	100.06

RATIONAL ANALYSIS.

Clay substance	22.11
Free silica	62.05
Impurities	9.97

The clay from the lower layers of the Welch-Trotter pit does not dry readily, and is used only when mixed with the upper leaner clay. The shrinkage of the lower clay is very excessive. The absence of non-plastic material of large grain permits a very slow transfer of water from the center of the brick. Thus the outside becomes dry and shrinks more rapidly than the center, thereby producing cracks.

Two samples of clay from the middle portion of the bed show the following chemical composition:

TABLE 51.

ANALYSES OF CLAYS, WEST POINT.

	No. 45	*No.* 47
Moisture (H_2O)	3.95	3.10
Volatile matter (CO_2)	5.12	3.75
Silicon dioxide (SiO_2)	71.45	76.86
Iron oxide (Fe_2O_3)	5.00	9.50
Aluminum oxide (Al_2O_3)	11.68	3.75
Calcium oxide (CaO)	1.45	1.25
Magnesium oxide (MgO)	.76	.45
Sulphur trioxide (SO_3)	.34	.34
Total	99.75	98.70

RATIONAL ANALYSIS.

Clay substance	28.55
Free silica	57.73
Impurities	7.55

Clay No. 45 requires 17 per cent of water to render it plastic. It shrinks about 6⅔ per cent. It burns without cracking to a red

color. The tensile strength of the raw brickettes is 92 pounds per square inch. The burned brickettes have a strength of 130 pounds per square inch.

This clay has about the proper amount of clay substances and the proper physical properties to make a good clay for the manufacture of a stiff-mud brick. The thickness of the layer is not sufficient to warrant its exclusive use. Therefore a mixture of top, bottom and middle clay is used.

Clay No. 47 is noticeable for its high silica content and the small amount of alumina. It has a peculiar texture and is somewhat light and spongy. Its total shrinkage is 5 per cent. It requires the addition of 19 per cent of water for molding. The raw clay has a tensile strength of 140 pounds per square inch. The burned brickettes have strength of 138 pounds per square inch. A medium burned brickette absorbs 10.52 per cent of water. The tensile strength is high when the small amount of clay substance is considered. The amount of impurities in the clay is in excess of the clay substance.

The clay from the top of the pit contains more silica and less alumina than the clay from the middle and lower portions of the pit. An analysis of a sample of the top clay is given below:

TABLE 52.

ANALYSIS OF SURFACE CLAY, WEST POINT.

	No. 40
Moisture (H_2O)	3.50
Volatile matter (CO_2)	2.52
Silicon dioxide (SiO_2)	75.95
Iron oxide (Fe_2O_3)	5.08
Aluminum oxide (Al_2O_3)	9.62
Calcium oxide (CaO)	1.25
Magnesium oxide (MgO)	.74
Sulphur trioxide (SO_3)	.34
Total	99.00

RATIONAL ANALYSIS.

Clay substance	24.33
Free silica	64.74
Impurities	7.41

The above mentioned clay may be molded by the addition of 18 per cent of water. The burned brickettes are red in color and free from cracks and checks. The raw clay has a tensile strength of 283

pounds. The total shrinkage is about 6 per cent. The increase in tensile strength over the clay from the middle portion of the pit is noticeable. The increase is doubtless due to the greater amount of clay substance.

CHICKASAW COUNTY.

GEOLOGY.

The eastern portion of Chickasaw County is underlain by the Ripley and Selma divisions of the Cretaceous. The western portion is underlain by the Porter's Creek and the Wilcox. The Lafayette, the residual Selma and the Columbia overlie the bed-rock formations. The clays used in the manufacture of brick are from these surface formations.

CLAY INDUSTRY.

Okolona.—At Okolona deposits of yellow clay, for the most part residual Selma, rest upon that formation. This clay is used by Hawkins and Hodges in the manufacture of brick. This brick plant was established in Okolona in 1895. The brick are molded in a stiff-mud machine of the auger-type. They are cut with an end-cut machine. The kilns in use are rectangular up-draft kilns of the clamp type. The clay in the pit is of two kinds: the upper is sandy, the lower is plastic and contains blue and red streaks. The limestone underlying the clay at this point has the following composition:

TABLE 53.

ANALYSIS OF SELMA LIMESTONE, OKOLONA.

	No. 19
Moisture (H_2O)	1.10
Volatile matter (CO_2 etc.)	34.20
Silicon dioxide (SiO_2)	8.70
Iron oxide (Fe_2O_3)	6.00
Aluminum oxide (Al_2O_3)	.00
Calcium oxide (CaO)	45.62
Magnesium oxide (MgO)	1.72
Sulphur trioxide (SO_3)	1.11
Total	98.45

Another sample of the limestone has the chemical properties indicated below:

TABLE 54.

ANALYSIS OF SELMA CHALK, OKOLONA.

	No. 12a
Moisture (H_2O)	6.35
Volatile matter (CO_2 etc.)	31.11
Silicon dioxide (SiO_2)	8.80
Iron oxide (Fe_2O_3)	4.08
Aluminum oxide (Al_2O_3)	2.86
Calcium oxide (CaO)	45.51
Magnesium oxide (MgO)	0.36
Sulphur trioxide (SO_3)	0.38
Total	99.45

The bottom clay is very plastic and is derived from the Selma by the solvent action of surface waters. The decomposition of pyrite contained in the chalk forms iron concretions called "buckshot," in the lower part of the clay bed. They are not uniformly distributed but are found in streaks in the lower layers and should be avoided, as they interfere with cutting and cause flaws in the brick unless crushed.

Houston.—The Pope Brick Manufacturing Company established a plant at Houston in 1903. The clay used is red clay, belonging probably to the Lafayette. The brick are molded in a stiff-mud machine of the plunger type. The brick are dried by heating under covered sheds. The burning is done in rectangular up-draft kilns. The clay is plastic, especially in the bottom layers, and care must be exercised in order not to dry too rapidly. The use of the non-plastic surface loam serves to increase the speed of drying.

New Houlka.—The New Houlka Brick Manufacturing Company's plant was established at New Houlka in 1904. The clay is prepared in a disintegrator and tempered in a pug mill. It is molded in an auger-type stiff-mud machine. The brick are cut with an end-cut machine and burned in rectangular up-draft kilns. The stratigraphy of the clay pit is as follows:

Section of Clay Pit, New Houlka.

	Feet
4. Yellow loam	2–3
3. Gray clay, very plastic	4–5
2. Grayish clay with iron concretions (buckshot)	1
1. Limestone with shells (Clayton)	...

Clays Nos. 2 and 3 have very similar properties to the Porter's Creek or Flatwoods clays. Since New Houlka lies within the edge of that area, these clays are probably residual clays from that group. Layer No. 4 may consist partly of this residual clay and partly of foreign material.

A sample of clay from No. 3 has the composition recorded below:

TABLE 55.

ANALYSIS OF BRICK CLAY, NEW HOULKA.

	No. 96	*No.* 95
Moisture (H_2O)	3.86	4.00
Volatile matter (CO_2 etc.)	3.60	6.30
Silicon dioxide (SiO_2)	75.85	71.75
Iron oxide (Fe_2O_3)	5.45	5.95
Aluminum oxide (Al_2O_3)	4.95	5.85
Calcium oxide (CaO)	1.87	2.05
Magnesium oxide (MgO)	.49	.14
Sulphur trioxide (SO_3)	.04	.48
Total	96.11	96.52

RATIONAL ANALYSIS.

Clay substance	12.52	14.79
Free silica	68.28	62.81
Impurities	7.86	8.62

No. 95 from No. 4
No. 96 from No. 3

The absorption of clay No. 96 is 12.96 per cent; tensile strength, raw, 75 pounds. The absorption of a mixture of Nos. 95 and 96 is 16 per cent; tensile strength, raw, 60 pounds; burned, 75 pounds; shrinkage, 5 per cent.

CHOCTAW COUNTY.

GEOLOGY.

Choctaw County lies within the area of the Wilcox Eocene, with a small outcrop of Claiborne in the southwestern corner. The mantle rock belongs to the Lafayette and the Columbia.

The surface clays have been used at Ackerman in the manufacture of brick. The plant is not now in operation. The brick were made by the soft-mud process and burned in scove kilns. There seems to be a suitable body of clay for the manufacture of brick just west of the Mobile, Jackson and Kansas City station. The clay is bluish in color and has a thickness of about 15 feet.

An exposure of the Wilcox and later formations may be seen in a

cut on the Illinois Central Railroad one-half mile east of Ackerman. At the bottom of the cut there are 10 feet of pink colored sand. Overlying the pink sand there are 10 feet of orange sand with little partings of clay. Near the top there is a thin layer of ironstone which has been broken up, the pieces being turned at various angles. On the slopes there is a bed of yellow loam which decreases in thickness toward the top until at the apex there is not more than 1 foot of it. The best clays for brick making in this country are to be found in the second bottom deposits. Some of the upland loams may be used in the soft-mud process.

COAHOMA COUNTY.

GEOLOGY.

The surface of Coahoma County is occupied by the recent alluvium deposited by the Mississippi River upon its flood plain. The rocks of the Wilcox formation underlie this alluvial deposit at a depth of from 25 to 50 feet.

At a number of places in Coahoma County the dark "buckshot" clay of the alluvium has been burned successfully for road ballast. There are several short sections of roads upon which the ballast has been used with satisfactory results. The burned clay ballast is said to be much more economical than gravel. The cost per mile for the burned clay ballast is about $1,500.

CLAY INDUSTRY.

Clarksdale.—An experiment in road building carried on at Clarksdale by the U. S. Bureau of Public Roads gave very satisfactory results. The experiment was made upon a piece of road having a length of 300 feet. The road was first plowed as deep as it was possible for a four-horse team to pull the plow. It was then cross-furrowed and pieces of wood were placed across the furrows resting upon the crests of the intervening ridges. The wood was then covered with clay and more wood placed upon the surface of the clay. This wood was covered with more clay. Fires were then kindled in the furrows beneath the wood. The burning of the wood reduced the overlying clay to a "clinker." After the clay had been burned it was rolled down and compacted forming a close, hard, non-plastic surface. The several items of cost were as follows:

TABLE 56.

COST OF BUILDING 300 FEET OF ROAD WITH BURNED CLAY BALLAST, CLARKSDALE.

30½ cords of wood at $1.30 per cord	$39.65
20 loads of bark and chips at $0.30	6.00
Labor at $1.25 per day and teams at $3.00 per day	38.30
Total cost of 300 feet	$83.95

Total cost per mile at this rate, $1,478.40.

The clay ballast has not the wearing qualities of the hard chert gravel, such as the Tishomingo gravel, but with proper care it can be made very serviceable, and in a land of such paucity of good road metal and great abundance of timber this method of road making has its advantages. It is to be hoped that further experiments will be tried in the Delta and in other parts of the State. By the use of its convict labor the State could conduct experiments of this kind upon the roads on and near Sunflower farm, using the timber cut from the land in the process of clearing

The alluvial clays of Coahoma County are used at Clarksdale for the manufacture of both brick and drain tile. The Clarksdale Brick and Tile Mfg. Company has opened a pit in which the following stratigraphical conditions exist:

Section of Clay Pit, Clarksdale.

	Feet
5. Soil and sandy loam	7
4. Dark colored clay (buckshot)	8
3. Sandy loam	12
2. Sands	3
1. Gravel bowlders in bottom	...

Samples of clay taken from beds Nos. 5 and 4 gave the results shown in analyses Nos. 62 and 61 respectively.

TABLE 57.

ANALYSES OF CLAYS USED BY THE CLARKSDALE BRICK AND TILE CO., CLARKSDALE.

	No. 62	*No.* 61
Moisture (H_2O)	2.81	6.78
Volatile matter (CO_2 etc.)	4.23	7.97
Silicon dioxide (SiO_2)	74.45	58.52
Iron oxide (Fe_2O_3)	3.38	6.87
Aluminum oxide (Al_2O_3)	11.62	16.20
Calcium oxide (CaO)	1.69	1.75
Magnesium oxide (MgO)	.94	.36
Sulphur trioxide (SO_3)	.43	.51
Total	99.55	98.96

RATIONAL ANALYSES.

	No. 5	No. 4
Clay substance	29.39	40.98
Free silica	60.89	39.47
Impurities	8.44	9.49

The clay from No. 5 has a total shrinkage of 6⅔ per cent; tensile strength raw, 115 pounds; burned, 155 pounds; requires 19 per cent of water. Clay from No. 4 has total shrinkage of 5 per cent; requires 18 per cent of water; tensile strength raw, 132 pounds; burned, 258 pounds.

The clay is prepared by the use of a granulator and disintegrator and after being tempered n a pug mill is molded in an auger, stiff-mud machine. The clay from layer No. 4 contains more clay than sand. Its shrinkage is excessive and it can not be used alone in the manufacture of brick or tile; when mixed with the non-plastic material from the other layers of the pit it produces a good grade of ware. Careful selection of clay and mixing is necessary to obtain the best results. Whenever a large proportion of the plastic clay is used difficulties of rapid drying of the wares are greatly increased. The burned brickettes have an absorption of 12.96 per cent.

The Rheinhart firm of Clarksdale also operates a plant for the manufacture of brick and drain tile. In the clay pit which they have opened in the alluvial deposit the following layers are encountered:

Section of Rheinhart Clay Pit, Clarksdale.

	Feet
4. Soil and sandy loam (top)	3
3. Sandy clay	8
2. Dark clay (buckshot)	5
1. Sand in bottom	...

The analysis of clay from layer No. 2 is here given:

TABLE 58.

ANALYSIS OF BUCKSHOT CLAY USED AT THE RHEINHART BRICK AND TILE FACTORY, CLARKSDALE.

	No. 63
Moisture (H_2O)	6.70
Volatile matter (CO_2 etc.)	8.31
Silicon dioxide (SiO_2)	59.47
Iron oxide (Fe_2O_3)	7.25
Aluminum oxide (Al_2O_3)	14.00
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	.83
Sulphur trioxide (SO_3)	.43
Total	98.49

RATIONAL ANALYSIS.

Clay substance	35.42
Free silica	40.03
Impurities	10.01

The gray "buckshot" clay is mixed with a more sandy clay for the manufacture of brick and drain tile. The amount of clay substance permits the addition of considerable non-plastic material without destroying the bonding power.

In the manufacture of the smaller size of tile a horizontal machine is used, but for the larger sizes a vertical attachment is employed. The brick and tile are burned in kilns of the beehive type.

DE SOTO COUNTY.

GEOLOGY.

The extreme western part of De Soto County lies within the alluvial plain of the Yazoo basin. The remainder of the country lies at a higher level and has a much more rugged topography. The hilly portion is covered with surfacial deposits of Lafayette, Loess and Columbia. The sub-formation of the county is the upper portion of Hilgard's Lignitic (Wilcox).

CLAY INDUSTRY.

Lake View.—At Lake View, a station on the Yazoo and Mississippi Valley Railroad, one-half mile south of the Tennessee line, the flood plain meets the bluffs. At a point where the railroad makes a cut through the bluffs the following section is revealed:

Section of Loess and Lafayette One-Half Mile South of Lake View.

	Feet
4. Soil	1
3. Brownish sandy loam (Loess)	10
2. Gravel and sand (Lafayette)	5
1. Gravel and conglomerate (Lafayette)	10

The gravels of Nos. 1 and 2 are largely white, yellow and blue flints. In some places they are cemented together, forming masses of pudding stone, or conglomerate of considerable size. The cementing substance is limonite. No. 1 is Lafayette and No. 2 is probably Lafayette, though the latter may be Natchez. No. 3 is Loess and its derivative, though no concretions or gastropod shells were found in it.

A sample of clay from No. 2 was collected for analysis and gave results as follows:

TABLE 59.

ANALYSIS OF CLAY, LAKE VIEW.

	No. 50
Moisture (H_2O)	1.31
Volatile matter (CO_2 etc.)	5.28
Silicon dioxide (SiO_2)	75.33
Iron oxide (Fe_2O_3)	5.60
Aluminum oxide (Al_2O_3)	7.80
Calcium oxide (CaO)	1.25
Magnesium oxide (MgO)	1.19
Sulphur trioxide (SO_3)	.60
Total	98.36

RATIONAL ANALYSIS.

Clay substance	19.73
Free silica	66.16
Impurities	9.64

The physical character of No. 2 is as follows: The total shrinkage is 3½ per cent; water required for plasticity, 17 per cent; tensile strength raw, 65 pounds per square inch; burned, 83 pounds; absorption, 13.33 per cent; color, cherry red. The clay lacks the plasticity essential to stiff-mud brick, but it may be used for soft-mud brick, or, by mixing with the more plastic "buckshot" clays of the bottom, it may be used by the stiff-mud methods.

About one mile south of Lake View is located the works of the Valley Brick and Tile Company. The products of their plant are brick, hollow blocks and drain tile. The brick and blocks are molded in a stiff-mud machine of the horizontal auger type. The brick are cut by an automatic side-cut machine. Two types of kilns are used, namely, an up-draft kiln of the rectangular, clamp type and a down-draft beehive kiln.

The clay used is obtained from alluvial deposits of the Yazoo basin. It burns to a red color but explodes and flies to pieces if the heat be applied too rapidly. In air-drying it shrinks 15 per cent, but its total shrinkage after burning is only 10 per cent, so that the air shrinkage is partly compensated by swelling in burning. The water required to render it plastic is 22 per cent. In the raw state the air-dried brickettes have a tensile strength of 183 pounds. When burned they exhibit a strength of 193 pounds. The chemical composition of a sample of the clay is as follows:

TABLE 60.

ANALYSIS OF ALLUVIAL CLAY, LAKE VIEW.

	No. 51
Moisture (H_2O)	5.15
Volatile matter (CO_2 etc.)	11.70
Silicon dioxide (SiO_2)	58.92
Iron oxide (Fe_2O_3)	7.45
Aluminum oxide (Al_2O_3)	11.75
Calcium oxide (CaO)	1.10
Magnesium oxide (MgO)	1.01
Sulphur trioxide (SO_3)	.48
Total	97.56

RATIONAL ANALYSIS.

Clay substance	29.72
Free silica	45.11
Impurities	10.04

Hernando.—At Hernando the surface formations are Lafayette and Columbia. The latter seems to be a modified, or at least a partly residual, form of the Loess. An outcrop in a ravine south of the station reveals the following stratigraphy:

Section of Ravine Near Hernando.

	Feet
5. Soil	1
4. Brown loam, light in color	6
3. Brown loam, dark in color	6
2. Gravel and red sand	10
1. Reddish clay	...

The rocks of Nos. 1 and 2 belong to the Lafayette, while those of 3 and 4 are Columbia. A sample of clay from No. 4 has the following physical properties: It requires 10 per cent of water to render it plastic. The tensile strength of the raw clay is 90 pounds; when soft burned its strength is only 85 pounds. It burns to a red color. The total shrinkage is only about 1 per cent. The loss of weight in drying and burning is 18 per cent. The burned brickettes have an absorption of 10.76 per cent.

GRENADA COUNTY.

GEOLOGY.

The subformation of the eastern part of Grenada County is the Wilcox (Lagrange). The Silicious Claiborne, or Tallahatta buhrstone, underlies the western part of the county. The mantle formations are the Lafayette, the Loess and the Columbia loam.

CLAY INDUSTRY.

Grenada.—At Grenada the Columbia loam clay is used in the manufacture of brick. The Carl Brick Company operates a plant south of the Illinois Central Railroad station. Brick are manufactured by the soft-mud process and are burned in rectangular, up-draft kilns of the scove type. About 8 feet of clay is exposed in the pit. The lower portion is much more plastic than the upper portion. Two samples of the clay have the following chemical properties:

TABLE 61.

ANALYSES OF COLUMBIA CLAY, GRENADA.

	No. 79	
Moisture (H_2O)	1.91	2.31
Volatile matter (CO_2 etc.)	3.34	2.83
Silicon dioxide (SiO_2)	73.44	73.11
Iron oxide (Fe_2O_3)	5.97	5.62
Aluminum oxide (Al_2O_3)	10.35	10.44
Calcium oxide (CaO)	1.87	1.15
Magnesium oxide (MgO)	1.12	.98
Sulphur trioxide (SO_3)	.13	.18
Total	98.14	96.62

RATIONAL ANALYSIS.

Clay substance	26.18	26.41
Free silica	61.27	60.84
Impurities	9.09	8.93

The more sandy upper portion of the clay is mixed with the lower plastic portion in the manufacture of brick. The sandy clay has a total shrinkage of 5 per cent. It requires the addition of 17 per cent of water to render it plastic. The tensile strength of the raw clay is 55 pounds per square inch. When burned it has a strength of 94 pounds per square inch. The burned brickettes have an absorption of 15.57 per cent. The lower clay requires 17.9 per cent of water to render it plastic. The total shrinkage is 7 per cent. The tensile strength in the raw state is 66 pounds per square inch. The burned brickettes have a strength of 127 pounds per square inch.

A shale-like clay outcrops along the banks of the Yalobusha River at Grenada. At the Bledsoe Brick Company's plant this clay has a thickness of 40 feet, as shown by the record of an artesian well drilled by Mr. Bledsoe.

TABLE 62.

RECORD OF ARTESIAN WELL AT THE BLEDSOE BRICK YARD, GRENADA.

	Thickness	Depth
Yellow loam and gray clay	9 feet	9 feet
White sand, water bearing	12 "	21 "
Dark clay shale	40 "	61 "
Sand and shale (water at 200 feet)	160 "	200 "
Greenish sand and clay	25 "	225 "
Sand and clay (artesian water at 465 feet)	240 "	465 "
Sand, and at 475 feet a hard flint rock	10 "	475 "
Sand and water	25 "	500 "

The clay is dark in color and of low specific gravity. The following analysis shows the chemical composition:

TABLE 63.

ANALYSIS OF SHALE-CLAY, GRENADA.

	No. 56a
Moisture (H_2O)	5.91
Loss on ignition (CO_2 etc.)	8.75
Silica (SiO_2)	61.80
Ferric oxide (Fe_2O_3)	3.88
Alumina (Al_2O_3)	16.50
Lime (CaO)	1.00
Magnesia (MgO)	.25
Sulphur trioxide (SO_3)	.19
Total	98.28

RATIONAL ANALYSIS.

Clay substance	41.74
Free silica	42.40
Impurities	5.82

Mr. O. F. Bledsoe thinks this clay is suitable for the manufacture of drain tile, but he has not yet given it a trial. The Bledsoe Brick and Tile Company was established in 1901. They have the requisite machinery for the manufacture of brick by the soft-mud, the stiff-mud or the dry-press process. The clay so far used is a surface clay, having a thickness of about 9 feet. The pit exhibits the following section:

Section of Clay Pit at Grenada.

	Feet
4. Brown sandy loam	2
3. Whitish clay	4
2. Dark colored joint clay	3
1. White sand	12

The pit is located on the second bottom of the Yalobusha River.

Holcomb.—At Holcomb, Fred Gulo established a brick plant in 1906. The brick are molded in a soft-mud machine operated by horse power. They are dried in the sun in an open yard. Some of the brick are repressed before being burned in up-draft, scove kilns. The clay used is a surface clay which is tempered by the use of sand. It is probably Columbia in age. The burned brick are red in color.

HINDS COUNTY.

GEOLOGY.

The formations occupying the subsurface of Hinds County are Jackson, Vicksburg, and Grand Gulf. All of these formations belong to the Tertiary period. The Lafayette and the brown loam phase of the Columbia and the alluvium of the Pearl River valley form the unconsolidated sediments of the mantle rock. The Columbia loam forms the surface of the greater part of the country, the Lafayette occupying the higher isolated areas.

CLAY INDUSTRY.

Jackson.—At Jackson the clay at the base of the brown loam is being used in the manufacture of brick. The W. B. Taylor plant was established in 1881, and has been in continuous operation since that time. The clay pit has the following layers:

Section of the Taylor Clay Pit, Jackson.

	Feet
3. Soil	1
2. Clay, brown, jointed in lower part	6–8
1. Yellowish clay with gravel in upper part	4

The chemical composition of a sample of clay from No. 2 is given below:

TABLE 64.

ANALYSIS OF BRICK CLAY, JACKSON.

	No. 73
Moisture (H_2O)	1.80
Volatile matter (CO_2 etc.)	4.37
Silicon dioxide (SiO_2)	75.21
Iron oxide (Fe_2O_3)	5.47
Aluminum oxide (Al_2O_3)	10.71
Calcium oxide (CaO)	.87
Magnesium oxide (MgO)	.93
Sulphur trioxide (SO_3)	.52
Total	99.88

RATIONAL ANALYSIS.

Clay substance	27.09
Free silica	62.62
Impurities	7.79

The above mentioned clay is used in the manufacture of brick. The whole section of the clay is taken and mixed. The lower portion of the clay has a joint structure, the faces of the blocks being covered with a white efflorescence. This may be a deposit of gypsum brought up from the underlying clay by circulating waters. The brown clay has an air shrinkage of 3½ per cent. The tensile strength of the raw clay is 50 pounds per square inch. The clay requires an addition of 17 per cent of water for plasticity.

The clay in No. 1 of the Taylor clay pit has the following chemical composition:

TABLE 65.

ANALYSIS OF BRICK CLAY, JACKSON.

	No. 72
Moisture (H_2O)	4.25
Volatile matter (CO_2 etc.)	8.01
Silicon dioxide (SiO_2)	67.72
Iron oxide (Fe_2O_3)	5.51
Aluminum oxide (Al_2O_3)	10.86
Calcium oxide (CaO)	.85
Magnesium oxide (MgO)	.70
Sulphur trioxide (SO_3)	.54
Total	98.44

RATIONAL ANALYSIS.

Clay substance	27.47
Free silica	12.77
Impurities	7.60

The gravel lying on this clay is probably Lafayette. The clay which rests upon the Jackson is probably residual clay from that formation. It has a total shrinkage of 8 per cent. It requires 17 per cent of water for plasticity. Its tensile strength raw is 75 pounds per square inch; burned, it has a strength of 87 pounds. The absorption of the burned brickettes is 11.11 per cent.

The Bullard Brick Mfg. Company also operates a plant at Jackson. They use the brown loam clay, which has a thickness varying from 6 to 9 feet (see Plate XXXV B). The clay contains gravel at the base and rests upon a stiff plastic clay which belongs to the Jackson formation. This company used a soft-mud machine for about three years, but abandoned its use because of excessive shrinkage in the clay. The plant was established in 1899. The brick are molded in a stiff-mud machine of the auger type. The brick are cut by the use of

PLATE XXIX.

A. POWER HOUSE OF THE BULLARD BRICK PLANT, JACKSON.

B. CLAY PIT OF THE BULLARD BRICK PLANT, JACKSON.

an automatic end-cut machine. The brick are dried in covered sheds; some are stacked and others placed on pallets. They are burned in up-draft kilns of the clamp type.

The brown loam, which is doubtless a modified form of the Loess, is probably not thicker than 20 feet anywhere in the county. It is the best brick clay in the county, but is not of the same quality in all parts of the county. In some deposits it lacks sufficient bonding power. In nearly all places it presents two phases, a loam phase in the upper part and a clay phase in the lower part of the deposit. The clay phase may be but poorly represented, in which case the deposit will not be suited to the manufacture of brick.

HOLMES COUNTY.

GEOLOGY.

Holmes County lies within the area which is underlain by the Claiborne group. The Tallahatta buhrstone forms the bed-rock of the northern part of the county, and the "Claiborne Calcareous" the southern part. The principal mantle rock formations belong to the Lafayette, the Loess, the Columbia and the Alluvium of the Yazoo delta.

CLAY INDUSTRY.

Lexington.—In the northern part of the town of Lexington, the stratigraphy of some of the surficial formations is revealed in numerous gullies or gulches. The soft, unconsolidated character of the sediments has developed a "bad land" type of topography. The general stratigraphic conditions are given below:

Section of the Lafayette, Lexington.

	Feet
6. Soil	1
5. Brownish colored loam and clay	6–10
4. Orange sand with white sandy clay gravel	10–15
3. White and purple sand and clay with small gravel	6–10
2. Larger gravel with some sand	3–5
1. Cross-bedded reddish sand	3–6

Layer No. 5 is doubtless Columbia loam. The remaining layers below belong to the Lafayette. These layers vary in thickness and composition from outcrop to outcrop. The gravels are for the most

part brown cherts, though there are some white and blue cherts, and some transparent quartz pebbles. Some of the cherts are fossiliferous. The shapes of some are irregular, but the majority are smooth and well rounded pebbles. The size of the pebbles vary from the size of a pea to a little larger than the size of a man's fist. The larger sizes are not numerous. The irregularity in the bedding of the gravel may be seen from figure 14.

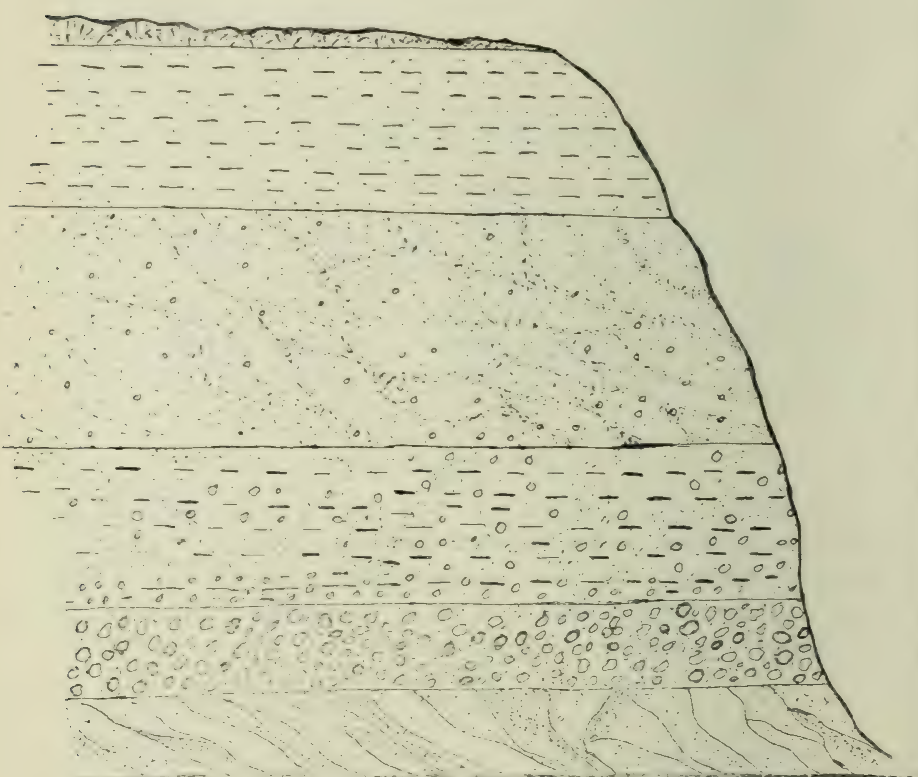


FIGURE 13. SECTION OF THE LAFAYETTE, LEXINGTON.

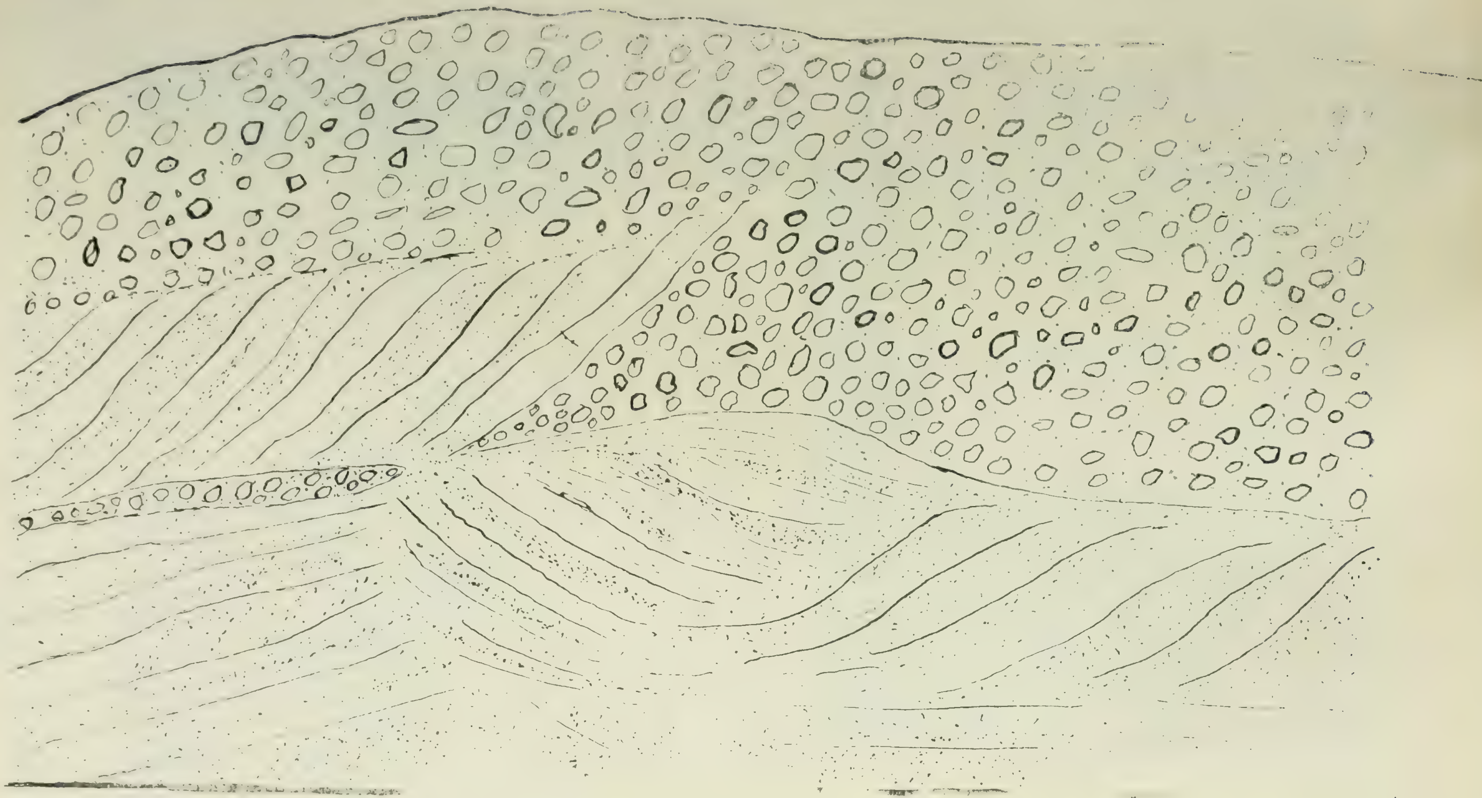


FIGURE 14. CROSS BEDDING IN THE LAFAYETTE, LEXINGTON.

A sample of clay from layer No. 5 has the following composition:

TABLE 66.

ANALYSIS OF COLUMBIA CLAY, LEXINGTON.

	No. 59
Moisture (H_2O)	1.56
Volatile matter (CO_2 etc.)	4.14
Silicon dioxide (SiO_2)	75.65
Iron oxide (Fe_2O_3)	6.20
Aluminum oxide (Al_2O_3)	8.70
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	1.60
Sulphur trioxide (SO_3)	.26
Total	99.31

RATIONAL ANALYSIS.

Clay substance	22.01
Free silica	65.42
Impurities	9.26

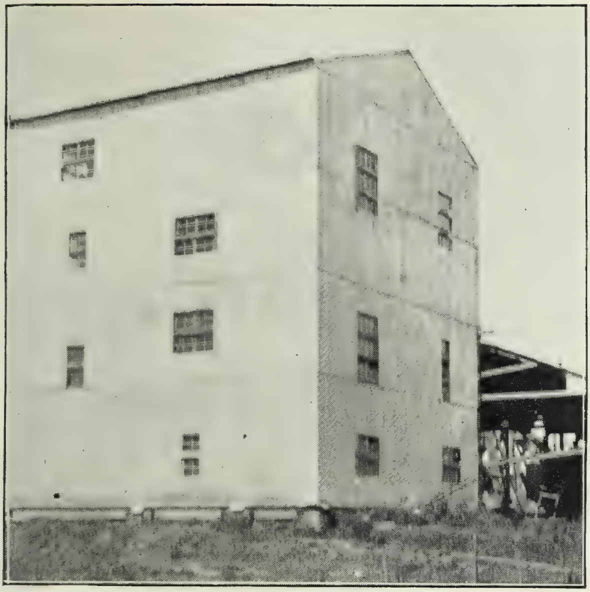
Clay No. 59 shrinks about 3 per cent in drying and burning. It requires the addition of 16 per cent of water to render it plastic. The tensile strength of the raw clay is 58 pounds per square inch. When burned it has a strength of 95 pounds per square inch. When allowed to dry in the open air it cracks badly. It lacks bonding power and could be used only by mixing with a more plastic clay.

Durant.—The Love Wagon Manufacturing Company has operated a brick plant at Durant since 1893. The first clay pit and yard was located east of the line of the Illinois Central Railroad. New machinery was installed in this yard in 1897. In 1905 this yard was abandoned and a new one opened in the western part of the town on a spur of the railroad.

The yard has been greatly enlarged and new machinery installed. The clay pit has been opened to a depth of 8 or 10 feet. The clay is brownish yellow in color, but contains streaks of gray clay which contain ironstone concretions of small size. Water is supplied to the plant from an artesian well. The record of this well shows a thickness of 40 feet for the surface formation. At a depth of 7 to 8 feet a hard stratum was encountered. Underlying the clay is a bed of sand. In the old pit the sand bed has a thickness of about 15 feet. Ironstone pebbles are very abundant in the lower part of the bed.

The clay is prepared in a granulator and disintegrator. It is

Plate XXX.



A. POWER HOUSE OF THE LOVE BRICK PLANT, DURANT.

B. UP-DRAFT CLAMP KILNS, DURANT.

tempered in a pug mill and molded in a stiff-mud machine. The brick are burned in rectangular up-draft kilns. A waste heat dryer is being installed.

KEMPER COUNTY.

GEOLOGY.

The northeastern part of Kemper County has for its subformations Cretaceous strata belonging to the Selma and Ripley epochs. The remainder of the county is occupied by Eocene rock. The mantle formations are Lafayette, Columbia and the residual deposits of the bed-rock.

CLAY INDUSTRY.

Wahalak.—At Wahalak the sticky Flatwoods clay rests upon a hard rock, probably sandstone. On Wahalak Creek, 1 mile south of Wahalak, there is exposed the following section:

Section on Wahalak Creek, One Mile South of Wahalak.

	Feet
3. Yellowish-red clay	6
2. Shally, friable sandstone	3
1. Blue limestone	3

A sample of clay from the well of D. V. Porter in Wahalak has an air shrinkage of 10 per cent and a tensile strength, raw, of 112 pounds per square inch. When burned its strength is 170 pounds. It requires 20 per cent of water for plasticity. The burned brickettes absorb 11.23 per cent of water. Mixed with 10 per cent coal the absorption is 12.5 per cent. Total shrinkage is 4 per cent; the water required for plasticity is 14 per cent. The raw clay has a tensile strength of 77 pounds per square inch; when burned its strength is 222 pounds. When mixed with 10 per cent of Selma clay from Agricultural and Mechanical College campus the absorption is 10 per cent; has a tensile strength, raw, of 111 pounds per square inch, and when burned 105 pounds per square inch; its air shrinkage is only 5 per cent; the amount of water required for plasticity is 14 per cent.

LAFAYETTE COUNTY.

GEOLOGY.

Lafayette County lies wholly within the Wilcox division of the Tertiary. Resting upon the clays and sands of this formation are

the Lafayette sand and clays and the Columbia loams. Many outcrops of fine pottery clays are found in the Wilcox in this county. The chemical composition of some of these clays are given in the table below:

TABLE 67.

ANALYSES OF CLAYS FROM THE WILCOX, LAFAYETTE COUNTY.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5
Moisture (H_2O)	.69	1.14	1.16	.90	1.64
Volatile matter (CO_2 etc.)	8.20	9.11	10.14	8.35	8.99
Silicon dioxide (SiO_2)	60.00	57.79	51.88	60.40	57.48
Iron oxide (Fe_2O_3)	.75	2.98	3.53	1.32	2.43
Aluminum oxide (Al_2O_3)	27.80	26.03	30.64	27.68	26.94
Calcium oxide (CaO)	1.38	.44	.58	1.08	.78
Magnesium oxide (MgO)	.00	.10	.60	.00	.27
Sulphur trioxide (SO_3)	.20	.24	.00	.00	.20
Total	99.02	97.83	98.53	99.73	98.73

RATIONAL ANALYSES.

Clay base	70.45	65.97	77.65	70.15	68.27
Free silica	17.35	17.85	4.87	17.93	16.15
Fluxing impurities	2.33	3.52	4.71	2.40	3.48

No. 1 is from Oxford, about 3 blocks east of the courthouse. No. 2 is from the street near the colored schoolhouse in Oxford. No. 3 is from Mr. Russell's farm, 3 miles northeast of Oxford. No. 4 is from the Tubbs farm, 3 miles south of Oxford. No. 5 is from the Wyley farm, 6 miles southwest of Oxford.

CLAY INDUSTRY.

College Hill Station.—The Brown loam clay is used at College Hill station, north of Oxford, by the Oxford Brick and Tile Company in the manufacture of pressed brick. The plant was first established south of Oxford near the oil mill, but the thickness of the clay was not adequate and the plant was moved to College Hill station. The plant was established in 1904.

The Brown loam of the county, by proper selection and mixture, may be used in the manufacture of brick by the soft-mud, stiff-mud and dry-press methods. Processes of denudation have removed the loam in many places to such an extent that the thickness is not sufficient to warrant the establishment of brick plants at such points. There are two phases of the loam, a top sandy phase and bottom clayey phase. The latter in some places is very poorly represented

Plate XXXI.

PUBLIC BUILDING AT DURANT BUILT OF MISSISSIPPI PRESSED BRICK.

and such places are undesirable localities for the manufacture of brick by either the stiff-mud or dry-press method. The white clays of the Wilcox furnish material for the manufacture of white or spotted brick and a fine grade of stoneware.

LAUDERDALE COUNTY.

GEOLOGY.

The bed-rock formations of Lauderdale County are of Tertiary age. The strata represented are the Wilcox and the Claiborne Both of these formations contain beds of clay. The Wilcox (Lagrange) contains beds of pottery clays. The mantle rocks are the Lafayette and the Columbia.

CLAY INDUSTRY.

Lockhart.—The Wilcox clays are utilized at Lockhart in the manufacture of stoneware by the Wedgewood Stoneware Company. The clay is grayish-white and has the following chemical composition:

TABLE 68.

ANALYSIS OF WILCOX STONEWARE CLAY, LOCKHART.

	No. 71
Moisture (H_2O)	3.14
Volatile matter (CO_2 etc.)	7.20
Silicon dioxide (SiO_2)	58.05
Iron oxide (Fe_2O_3)	1.05
Aluminum oxide (Al_2O_3)	27.79
Calcium oxide (CaO)	2.00
Magnesium oxide (MgO)	.25
Total	99.48

RATIONAL ANALYSIS.

Clay base	70.42
Free silica	15.42
Fluxing impurities	3.30

The Lockhart clays have been used in Meridian in the manufacture of brick. The brick are said to be extremely hard and to approach vitrified paving brick in physical properties.

The Columbia loam has been used at Lockhart in the manufacture of brick by Mr. B. R. Brown. The brick are red in color. They are burned in up-draft kilns of the scove type.

A sample of gray clay from the Wilcox formation on Mr. Brown's farm at Lockhart has the following chemical composition:

TABLE 69.

ANALYSIS OF WILCOX CLAY, LOCKHART.

	No. 72*a*
Moisture (H_2O)	4.29
Volatile matter (CO_2 etc.)	7.74
Silica (SiO_2)	58.21
Iron oxide (Fe_2O_3)	.83
Aluminum oxide (Al_2O_3)	27.23
Calcium oxide (CaO)	.65
Magnesium oxide (MgO)	.41
Total	99.36

RATIONAL ANALYSIS.

Clay substance	69.00
Free silica	16.44
Impurities	1.89

Meridian.—At Meridian the Columbia clay is used in the manufacture of brick by the Bonita Manufacturing Company. The clay is prepared by the use of a granulator and tempered in a pug mill. The brick are molded in an end-cut, auger-type, stiff-mud machine. The brick are burned in rectangular updraft kilns. A sample of the tempered clay has the following composition:

TABLE 70.

ANALYSIS OF BRICK CLAY, MERIDIAN.

	No. 93
Moisture (H_2O)	3.72
Volatile matter (CO_2 etc.)	5.34
Silicon dioxide (SiO_2)	71.58
Iron oxide (Fe_2O_3)	6.95
Aluminum oxide (Al_2O_3)	10.77
Calcium oxide (CaO)	.50
Magnesium oxide (MgO)	.19
Sulphur trioxide (SO_3)	trace
Total	99.05

RATIONAL ANALYSIS.

Clay substance	27.23
Free silica	55.12
Fluxing impurities	7.64

LEE COUNTY.

GEOLOGY.

The Selma chalk forms the bed-rock of Lee County. It varies in thickness from a few feet on its eastern border to 600 feet on its

western border. The surface formations are isolated areas of the Lafayette, and the residual clay of the Selma and the Columbia loam. The clays of these mantle rocks are being utilized in the manufacture of brick at Baldwyn, Saltillo, Verona and Nettleton. Brick were also manufactured at Tupelo.

CLAY INDUSTRY.

Baldwyn.--At Baldwyn, the Baldwyn Brick and Tile Company has opened a pit containing the following layers:

Section of Pit of the Baldwyn Brick & Tile Co., Baldwyn.

	Feet
4. Soil	1
3. Sandy loam or sand	1
2. Plastic red and blue clay	6–8
1. Sand (depth in well)	7

The bottom portion of No. 2 contains small ironstone concretions, "buckshot." The clay from this layer has a total shrinkage of 8 per cent. The raw clay has a tensile strength of 188 pounds per square inch. The soft-burned brickettes have a strength of 130 pounds per square inch. The addition of 20 per cent of water is required for plasticity. When mixed with 10 per cent of coal the clay has a total shrinkage of 6 per cent. Its tensile strength, raw, is 153 pounds. When hard burned it has a strength of 187 pounds per square inch. The amount of water required for plasticity is 20 per cent and the loss in burning 10 per cent. When mixed with 10 per cent of cinders it has a total shrinkage of 6 per cent and requires 16 per cent of water to render it plastic. It loses 8 per cent of its weight in burning. The tensile strength of the raw clay is 138 pounds per square inch. When burned it has a tensile strength of 244 pounds per square inch.

The composition of a sample of the clay is given below:

TABLE 71.

ANALYSIS OF CLAY USED BY THE BALDWYN BRICK AND TILE CO., BALDWYN.

	No. 114
Moisture (H_2O)	3.60
Volatile matter (CO_2)	.04
Silicon dioxide (SiO_2)	72.72
Iron oxide (Fe_2O_3)	3.95
Aluminum oxide (Al_2O_3)	12.55
Calcium oxide (CaO)	6.90
Magnesium oxide (MgO)	.27
Sulphur trioxide (SO_3)	.08
Total	100.11

RATIONAL ANALYSIS.

Clay substance	41.75
Free silica	43.52
Impurities	11.20

Saltillo.—At Saltillo the plant of the Saltillo Brick Manufacturing Company is located about ½ mile south of the Mobile and Ohio Railroad station. This company uses a surface clay in the manufacture of brick by the stiff-mud process. The machine is of the plunger type. No disintegrator or pug mill is used in preparing the clay. The brick are burned in rectangular up-draft kilns. Red is the prevailing color of the burned brick.

The clay in the upper part of the pit is a sandy red clay overlying a sandstone. Both of these layers are probably of Lafayette age. The lower part of the pit is occupied by a more plastic clay which is probably residual Selma, since the latter underlies it. The record of the well at the brick plant shows the thickness of the Selma at this point to be about 330 feet.

The lower clay is too plastic to be used alone. When mixed in the proper proportion with the sandy upper clay it makes a good brick.

Verona.—The Verona Brick and Tile Company's plant is located about ½ mile north of the Mobile and Ohio Railroad station at Verona. Two varieties of surface clay are employed in the manufacture of brick. The bottom of the pit rests upon the Selma chalk. Overlying this bed is a plastic clay which has doubtless been derived from the Selma by decomposition processes. Resting upon the lower clay is a red sandy clay which probably belongs to the Lafayette. In the manufacture of brick these two clays are mixed. The clay is tempered in a horizontal pug mill and molded in a stiff-mud machine of the auger type. The cutter is a side-cut machine. The brick are dried in rack and pallet driers. They are burned in up-draft kilns of the clamp variety.

The auger motion produces laminations in this clay unless it has been carefully tempered. When too large a proportion of the bottom clay is used the difficulties of drying are greatly augmented. Thorough disintegration and mixing are essential to the best results. Gathering the clay too close to the limestone surface may result in inclusions which cause flaws in the brick.

Nettleton.—The Nettleton Manufacturing Company operates a brick plant at Nettleton. The clay used is from a surface deposit consisting of clay, loam and sand. It is probably of Lafayette age for the most part. The total thickness of the formation is about 20 feet, as is shown by well records in the town. The upper portion consists of yellowish loam, below which there is a sandy layer, then a fat jointed clay containing sandy streaks. The clay is prepared by the use of a granulator and a disintegrator. It is then tempered in a pug mill and molded in a soft-mud molding machine, operated by steam power. The molds contain six bricks. They are sanded to prevent the clay from sticking. The brick are placed upon pallets, which are placed on racks under covered sheds. The brick are burned in rectangular up-draft kilns.

LEFLORE COUNTY.

GEOLOGY.

The alluvium of the Yazoo-Mississippi flood plain occupies the surface of the greater part of Leflore County. Beneath this overburden, which has an average thickness of about 50 feet, lies the Claiborne formations. Two rather distinct types of the alluvium are recognizable. The first type is a sandy loam which occupies the surface bordering the streams. The second type is a black, sticky clay which occupies the surface of the inter-stream areas and is called locally "buckshot" land. Vertically the one type may succeed the other within a few feet. The change from one type to the other in vertical and horizontal succession was produced by the shifting or meandering of the depositing stream. When the stream overflows, the water, which passes from the stream's course out over the flooded plain, begins to lose its velocity as it leaves the banks and to drop its load, the heavier particles being deposited first, the finer clay particles being carried to the inter-stream areas.

The clays of this alluvial deposit are used in the manufacture of brick at Greenwood, in Leflore County.

CLAY INDUSTRY.

Greenwood.—The Success Brick and Tile Company of Greenwood is using clay from a pit which has the following stratigraphic relations:

Section of Clay Pit at Greenwood.

	Feet
4. Joint clay, black to gray in color (top)	5
3. Very sandy clay	4
2. Reddish tinged clay	4
1. Blue clay	6

The full thickness of No. 1 is not exposed. Chemical analyses of layers Nos. 1 and 2 were made with the results given in Table No. 72.

TABLE 72.

ANALYSES OF CLAYS, GREENWOOD.

	No. 48	*No.* 98	*No.* 99
Moisture (H_2O)	5.52	3.22	5.75
Volatile matter (CO_2 etc.)	4.75	3.06	6.55
Silicon dioxide (SiO_2)	72.25	73.40	59.32
Aluminum oxide (Al_2O_3)	8.44	6.81	11.45
Iron oxide (Fe_2O_3)	6.56	4.19	10.62
Calcium oxide (CaO)	1.00	1.12	1.50
Magnesium oxide (MgO)	.63	.44	1.37
Sulphur trioxide (SO_3)	.17	.17	2.98
Total	99.32	92.41	99.54
RATIONAL ANALYSES.			
Clay substance	21.35	17.22	26.86
Free silica	59.34	65.40	46.84
Impurities	8.36	5.92	12.48

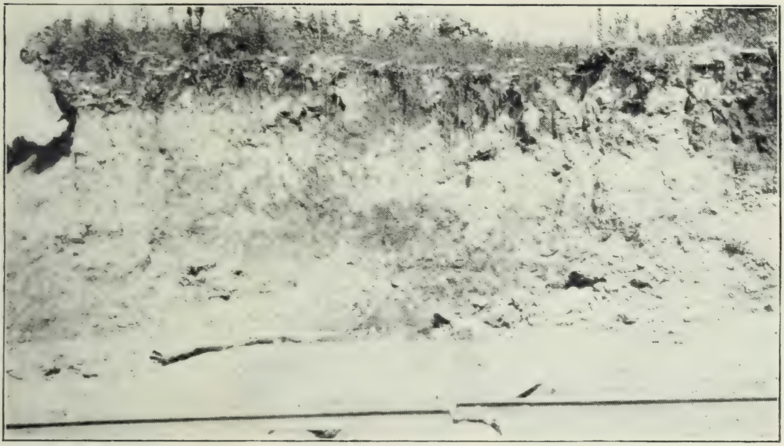
Analysis No. 48 is from bed 1 of the above section; No. 98 is from bed 2, and No. 99 is from bed 3.

The different layers of clay from the above mentioned pit are mixed together in the manufacture of brick. The brick are molded in a stiff-mud auger-type machine with an end-cut. The elevating cars are used in the yard. The clay is prepared in a granulator and pug mill.

Mr. W. O. Bacon also owns and operates a brick plant at Greenwood. He uses a dark, alluvium clay. The thickness of the clay in the pit is about 8 feet; all of the clay is utilized. The brick are molded in a steam-power machine of the soft-mud type. They are dried in sheds in which they are placed on pallets. The brick are burned in up-draft kilns of the clamp type. An analysis of the clay was made with the results shown in No. 99. Some of the clay in the pit is more siliceous than the sample taken.

Minter City.—At Minter City the Cowgill Drain Tile Manufacturing Company uses the alluvium clay in the manufacture of brick and drain tile. Their pit is opened to a depth of 8 feet, the clay being used from

PLATE XXXII.



A. BROWN LOAM AND LAFAYETTE OVERLYING THE JACKSON, CANTON CLAY PIT.

B. STRATIFIED LAFAYETTE WITH TALUS, RAILROAD CUT, NEWTON.

top to bottom. The clay varies somewhat in composition from top to bottom of the pit.

Three samples of clay from the pit were analyzed with the following results: No. 55 from near the top, No. 56 from the middle portion, and No. 57 from the bottom

TABLE 73.

ANALYSES OF ALLUVIAL CLAYS, MINTER CITY.

	No. 55	*No.* 56	*No.* 57
Moisture (H_2O)	5.00	4.47	3.75
Volatile matter (CO_2 etc.)	10.81	8.17	7.75
Silicon dioxide (SiO_2)	63.27	62.18	65.66
Iron oxide (Fe_2O_3)	6.32	8.20	5.40
Aluminum oxide (Al_2O_3)	10.43	12.80	10.90
Calcium oxide (CaO)	1.10	1.50	1.35
Magnesium oxide (MgO)	.94	.79	1.01
Sulphur trioxide (SO_3)	.48	.31	.61
Total	98.25	98.42	96.24

RATIONAL ANALYSES.

Clay substance	26.36	32.38	27.57
Free silica	52.02	47.13	52.85
Impurities	8.84	10.80	8.38

Clay No. 55 requires the addition of 20 per cent of water to render it plastic. It has a total shrinkage of about 4 per cent. In the raw state it has a tensile strength of 102 pounds per square inch and of 218 pounds when burned. The absorption of the burned brickettes, made from different layers and burned to different degrees of hardness, varies from 5 to 16.41 per cent. The average per cent of absorption for 7 brickettes was 13.06 per cent.

LOWNDES COUNTY.

GEOLOGY.

The subsurface of Lowndes County is formed of Cretaceous strata belonging to the Tuscaloosa, the Eutaw and the Selma divisions. The mantle rock formations are the Lafayette, the Columbia and the residual Selma. Excellent outcrops of the Eutaw are found in the bluffs of the Tombigbee River.

CLAY INDUSTRY.

Columbus.—The Columbus Brick Manufacturing Company, operated by Puckett and Lindamood, was established at Columbus in 1900.

This company operates two plants at Columbus. Both are located upon the second bottom of the Tombigbee River. The clay in the first pit is about 12 feet thick and rests upon sand and gravel. The upper portion is a yellow loam. The lower clay is blue in color, and near the bottom contains some limestone and pebbles.

The clay in the second pit has a yellowish brown layer at the top, then a body of blue and yellow clay with a blue clay at the bottom. The last rests upon a bed of sand. Both common and repressed brick are manufactured. The brick are molded in a stiff-mud end-cut machine. They are dried in open sheds and in steam dryers. The brick are burned in rectangular up-draft kilns of the clamp type.

The Tombigbee second bottom clays furnish the best clays for the manufacture of brick in Lowndes County. They are probably Columbia in age. They rest upon sand and gravels belonging to the Lafayette

MADISON COUNTY.

GEOLOGY.

The Vicksburg and Jackson formations of the Tertiary are the sub-formations of Madison County. The surficial deposits belong to the Lafayette and the Columbia (brown loam phase). The last named formation furnishes the brick material of the county as far as the present development of that industry is concerned.

CLAY INDUSTRY.

Canton.—The Canton Brick Mfg. Company at Canton operates a plant near the Illinois Central Railroad north of the station. Three kinds of clay are exposed in the pit, which exhibits the following stratigraphy:

Section of Clay Pit at Canton.

	Feet
5. Soil	1
4. Brownish loam	4
3. Yellow clay	3
2. Red joint clay	3
1. Blue and yellow clay	...

The clay from No. 1 is residual Jackson. The clay from Nos. 2 and 3 belong to the Lafayette, and that from No. 4 is Columbia.

The lowest clay is very plastic and has a high shrinkage, so that it cannot be used alone. It is either mixed with the clay above it

PLATE XXXIII.

ALLISON CLAY PIT, HOLLY SPRINGS.

or with 10 per cent crushed cinders. The cinders facilitate drying and shorten the time of burning by about 24 hours. The clay from No. 4 has a total shrinkage of 5 per cent. Its tensile strength in the raw state is 140 pounds per square inch. When burned it exhibits a strength of 316 pounds per square inch. It requires 16 per cent of water to render it plastic. It loses 20 per cent in weight in drying and burning. Its absorption is 8.33 per cent.

TABLE 74.

ANALYSES OF CLAYS, CANTON.

	No. 87	*No.* 88	*No.* 89
Moisture (H_2O)	2.87	2.70	4.67
Volatile matter (CO_2)	3.63	3.10	1.95
Silicon dioxide (SiO_2)	79.28	73.22	73.00
Iron oxide (Fe_2O_3)	4.12	5.77	5.47
Aluminum oxide (Al_2O_3)	4.28	9.58	9.53
Calcium oxide (CaO)	.82	2.35	3.32
Magnesium oxide (MgO)	.36	.18	.27
Sulphur trioxide (SO_3)	.42	.40	.70
Total	95.98	97.30	98.91
RATIONAL ANALYSIS.			
Clay substance	11.33	24.23	24.11
Free silica	72.43	58.57	58.42
Impurities	5.72	8.70	9.76

The clay from No. 2 of the above section is more plastic and shrinks more in drying. It is red in color and has a joint structure. It shrinks in all about 8 per cent and requires the addition of 16 per cent of water. The tensile strength of the raw clay is about 8 per cent and requires the addition of 16 per cent of water to render it plastic. The tensile strength of the raw clay is 102 pounds per square inch. When burned its tensile strength is 275 pounds. Its total loss of weight in drying and burning is 27 per cent, its absorption is 8.33 per cent.

MARSHALL COUNTY.

GEOLOGY.

The subformation of Marshall County is the Wilcox (Lagrange) division of the Tertiary. The formation consists of clays and sand. The clays contain many outcrops of white pottery clays. The mantle-rock formations are the Lafayette sands and clays and the Columbia (brown loam phase). The stratigraphic relations of these formations are presented in the record of the Holly Springs town well.

Record of Holly Springs Well.

	Thickness	Depth
10. Reddish clay (Columbia)...........	20 feet	20 feet
9. Red sand (Lafayette).............	87 "	107 "
8. Sand rock (Lafayette).............	1 foot	108 "
7. Clay (Wilcox—Lagrange)..........	52 feet	160 "
6. Hard sandstone (Wilcox—Lagrange)	.5 foot	160.5 "
5. Clay and sandstone (Wilcox—Lagrange)......................	139.5 feet	300 "
4. Fine water bearing sand (Wilcox—Lagrange).....................	40 "	340 "
3. Pipe clay (Wilcox—Lagrange)......	13 "	353 "
2. Coarse sand (Wilcox—Lagrange)....	4 "	357 "
1. Sticky clay (Porter's Creek?).......	43 "	400 "

All layers between No. 8 and No. 1 doubtless belong to the Wilcox (Lagrange). No. 1 may be Porter's Creek (Flatwoods).

CLAY INDUSTRY.

Holly Springs.—The white clays from the Wilcox are being used at Holly Springs in the manufacture of stoneware. Two potteries are operated in this place, one by the Holly Springs Stoneware Company and the other by the Allison Stoneware Company. Both manufacture a general line of stoneware and both manufacture the fire brick used in their own kilns. These brick are manufactured from clays found near Holly Springs. A highly silicious clay is mixed with the white plastic clays which are used in the manufacture of stoneware. The chemical composition of the former is given below. (Bulletin No. 3, A. and M. College, 1905.)

TABLE 75.

ANALYSIS OF FIRE CLAY, HOLLY SPRINGS.

	No. 25*a*
Moisture (H_2O)........	.87
Volatile matter (CO_2 etc.)........	1.93
Silicon dioxide (SiO_2)........	88.52
Ferric oxide (Fe_2O_3)........	1.64
Aluminum oxide (Al_2O_3)........	5.26
Calcium oxide (CaO)........	.73
Magnesium oxide (MgO)........	.13
Sulphur trioxide (SO_3)........	.43
Total........	99.51

RATIONAL ANALYSIS.

Clay base........	13.33
Free silica........	80.45
Fluxing impurities........	2.50

PLATE XXXIV.

A. TYPICAL EROSION IN COLUMBIA LOAM, HOLLY SPRINGS.

B. LAFAYETTE OVERLYING WILCOX, HOLLY SPRINGS.

The fire brick manufactured from above mentioned clay have been used for about 25 years in some of the kilns without removal. The clay burns to a slightly pink color which disappears before vitrification, leaving the brick white or light cream in color. The sand grains in the clay are large. Some grains are as large as grains of wheat and of a clear, transparent, quartz variety.

The stoneware clays used by the Holly Springs potteries have the following chemical properties:

TABLE 76.

ANALYSES OF STONEWARE CLAYS, HOLLY SPRINGS.

	No. 20*a*	*No.* 19*a*
Moisture (H_2O)	1.51	.94
Volatile matter (CO_2 etc.)	8.07	6.64
Silicon dioxide (SiO_2)	61.69	67.70
Iron oxide (Fe_2O_3)	2.04	3.04
Aluminum oxide (Fe_2O_3)	24.91	19.69
Calcium oxide (CaO)	.34	1.06
Magnesium oxide (MgO)	.83	.58
Sulphur trioxide (SO_3)	.20	.19
Total	99.59	99.84

RATIONAL ANALYSIS.

Clay base	63.13	49.90
Free silica	23.47	37.49
Fluxing impurities	3.21	4.68

No. 20a is from the Allison clay pit, and No. 19a is from the Holly Springs Stoneware Company's pit. These pits are only a few rods apart and are located about 1¼ miles east of Holly Springs.

The Holly Springs Brick Mfg. Company (Erby Bros.) uses the brown loam clay in the manufacture of brick by the soft-mud process. The brick are molded by hand, dried in the open air and burned in a rectangular up-draft kiln. The clay varies in composition from a sandy loam at the top to a plastic joint clay in the bottom of the pit. The thickness of the deposit is 5 to 6 feet. A sample of clay taken from near the bottom of the pit was analyzed with the following results:

TABLE 77.

ANALYSIS OF BRICK CLAY, HOLLY SPRINGS.

	No. 111
Moisture (H_2O)	1.08
Volatile matter (CO_2 etc.)	2.11
Silicon dioxide (SiO_2)	80.76
Iron oxide (Fe_2O_3)	4.50
Aluminum oxide (Al_2O_3)	8.50
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	.45
Sulphur trioxide (SO_3)	.04
Total	98.94

RATIONAL ANALYSIS.

Clay substance	21.50
Free silica	70.67
Impurities	6.49

The amount of water which the above mentioned clay requires for plasticity is 19 per cent. It has a total shrinkage of 3 per cent. The raw brickettes have a tensile strength of 42 pounds, and when soft burned the strength is 45 pounds per square inch. The loss of weight in water-smoking and burning is 16 per cent.

MONTGOMERY COUNTY.

GEOLOGY.

The subformations of Montgomery County are the Wilcox (Lagrange) and the Tallahatta buhrstone (Silicious Claiborne). The surface formations belong to the Lafayette and the brown loam phase of the Columbia, which is widely distributed over the county.

CLAY INDUSTRY.

Winona.—The Columbia formation is used at Winona in the manufacture of brick. The Jessty Brick and Lumber Company manufactures brick by the dry-press process. They use a mixture of brown loam clay and a white clay from the Lafayette. The clay pit from which the white clay is taken is from an outcrop on the Southern Railroad about 1 mile west of town. It burns white and leaves white specks on the surface of the brick, presenting an attractive appearance. It also reduces the shrinkage of the brown clay and raises its fusion point.

The brown loam clays and the Wilcox clays are the sources of the principal brick material of this county.

MONROE COUNTY.

GEOLOGY.

The substrata of Monroe County belong to the Tuscaloosa, the Eutaw (Tombigbee), and the Selma. The surficial formations are the Lafayette sands and clays and the Columbia loams. The second bottom of the Tombigbee River, which crosses the county from north to south, is made up of sand and gravel, overlying which is a bed of clay grading into a loam at the top. The river has cut its trench into the soft rock of the Eutaw, and for the greater part of its distance marks the boundary between the Eutaw and the Selma; the higher Eutaw bluff on the west side of the stream being capped with the Selma. When not removed by erosion these higher bluffs are mantled with Lafayette and Columbia.

CLAY INDUSTRY.

Aberdeen.—At Aberdeen, just south of the waterworks, the Lafayette rests upon the eroded surface of the Eutaw. The line of contact is quite clearly marked in this instance by a thin layer of friable, whitish sandstone. The section exposed is as follows:

Section at Aberdeen.	Feet
2. Orange colored sand with some clay lenses, crossbedded with some joint clay at the top	12
1. Greenish sand (Eutaw)	20

At a lower horizon, on the river bank south of the bridge, about 30 feet of bluish gray sand containing some clay is exposed. In places the sand contains fossils and micaceous concretions containing iron pyrites. There are also some sandstone concretions, and in one exposure a rather persistent layer of friable sandstone from 1 to 2 feet in thickness. The clay pit belonging to the Aberdeen Sand-Lime Brick Company is located on the second bottom of the Tombigbee River. The clay is not being used at the present time, as the company is engaged in the manufacture of sand-lime brick. The old clay pit exhibits the following section:

Old Clay Pit at Aberdeen.	Feet
3. Sandy loam soil	1
2. Joint clay, blue in places	7
1. Sand	...

The clay from No. 2 has a tensile strength in the raw state of 87 pounds per square inch. It has a total shrinkage of 10 per cent and loses 11 per cent in weight in being water-smoked and burned. When mixed with 10 per cent coal the clay has a total shrinkage of 6 per cent and requires 17 per cent of water to render it plastic. Raw, it has a tensile strength of 140 pounds per square inch, and burned the strength is 263 pounds per square inch. Loss of weight in burning is 10 per cent. The burned brickettes have an absorption of 12.24 per cent. When mixed with 10 per cent of cinders its shrinkage is 6 per cent. In the raw state its strength is 175 pounds; burned, 300 pounds. A sample of the clay has the following chemical composition:

TABLE 78.

ANALYSIS OF JOINT CLAY, ABERDEEN.

	No. 103
Moisture (H_2O)	4.95
Volatile matter (CO_2 etc.)	4.92
Silicon dioxide (SiO_2)	71.13
Iron oxide (Fe_2O_3)	7.75
Aluminum oxide (Al_2O_3)	9.12
Calcium oxide (CaO)	.42
Magnesium oxide (MgO)	.63
Sulphur trioxide (SO_3)	.08
Total	99.00

RATIONAL ANALYSIS.

Clay substance	23.07
Free silica	60.41
Impurities	8.88

Amory.—At Amory the Tombigbee second bottom clay is used by two companies in the manufacture of brick. The stratigraphy of the formation at this point is shown by the following well record:

General Section of Amory Wells.

	Thickness	Depth
Surface loam and clay (Columbia?)	15 feet	15 feet
Gravel, water-bearing (Lafayette?)	25 "	40 "
Blue sand (Eutaw)	100 "	140 "
Sand, water-bearing (Eutaw)	50 "	190 "

The L. H. Tubbs Brick Manufacturing Company began the manufacture of brick at Amory in 1894. They use a stiff-mud machine of the plunger type.

Section of Clay Pit, Amory.

	Feet
4. Sandy soil	1
3. Yellowish loam	3
2. Joint clay, bluish and reddish tints	7
1. Sand and gravel	5

There is no distinct line of separation between 2 and 3. The clay of No. 2 requires 14 per cent of water for plasticity. It has a total shrinkage of 6 per cent. Its tensile strength, raw, is 100 pounds per square inch, and burned, it has a strength of 220 pounds. It absorbs 11.86 per cent of water in the soft burned stages. Mixed with 10 per cent of coal its physical properties are: Total shrinkage, 6⅔ per cent; tensile strength, raw, 150 pounds; burned, 273 pounds. Mixed with 10 per cent of cinders, its physical properties are: Shrinkage, 5 per cent; tensile strength, raw, 155 pounds; burned, 300 pounds per square inch.

The chemical composition of a sample of No. 3 is given below:

TABLE 79.

ANALYSIS OF YELLOW LOAM CLAY, AMORY.

	No. 94
Moisture (H_2O)	5.20
Volatile matter (CO_2 etc.)	5.10
Silicon dioxide (SiO_2)	71.04
Iron oxide (Fe_2O_3)	7.92
Aluminum oxide (Al_2O_3)	9.27
Calcium oxide (CaO)	.87
Magnesium oxide (MgO)	.31
Sulphur trioxide (SO_3)	trace
Total	99.71

RATIONAL ANALYSIS.

Clay substance	23.45
Free silica	56.86
Fluxing impurities	9.10

Mr. C. C. Camp has operated a brick plant at Amory since 1896. In 1904 he installed new machinery. The clay is molded in a stiff-mud machine of the auger type. The die is a double bar die. The

cutter is an automatic end-cut machine. The clay pit is near that of the other yard, and the stratigraphic conditions are similar. The brick are burned in rectangular up-draft kilns.

NEWTON COUNTY.

GEOLOGY.

The southwestern corner of Newton County is underlain by the Jackson formation. The remainder of the county is underlain by the Claiborne. The mantle rocks belong to the Lafayette and the Columbia and residual clays form the bed-rock formations.

CLAY INDUSTRY.

Newton.—The surface formations are used in the manufacture of brick at Newton. The Hancock Brick Company operates a plant south of the Alabama and Vicksburg Railroad, west of town. The brick are dried under a large shed open at both ends. They are burned in rectangular up-draft kilns.

The clay is reddish with a yellow loam overlying it. The absorption of the clay in the bottom layer is 9.52 per cent, and the absorption of that in the top layer is 13.79 per cent.

In a railroad cut on the Mobile, Jackson and Kansas City Railroad, south of town, there is an exposure of the following formations:

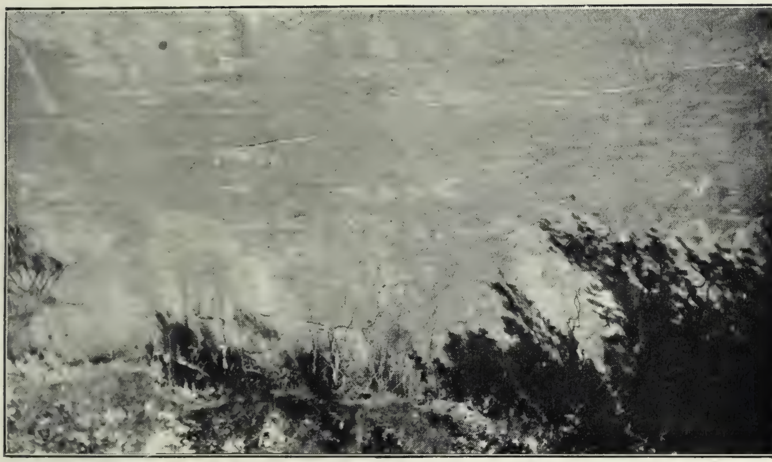
Section of Surface Formations at Newton.

	Feet
3. Yellow loam with some pebbles	6–8
2. Orange sand with silicious pebbles	6–10
1. Red sand with white clay partings	6–8

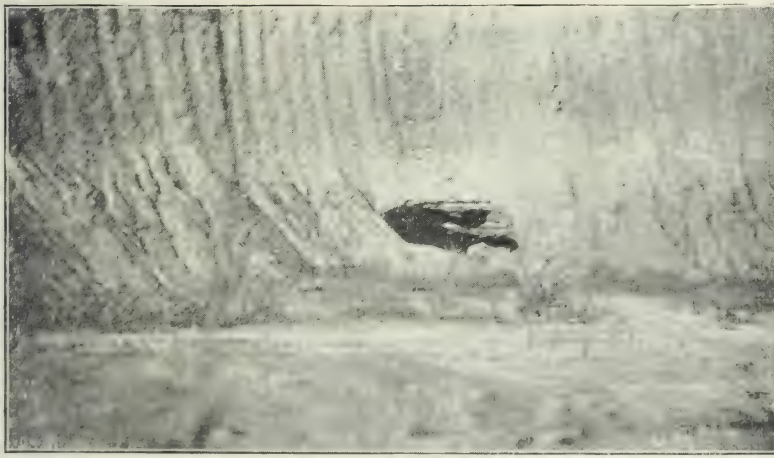
No. 1 contains partings of clay and has an irregular stratification. In some places the partings are in the nature of very fine white lines, as though they had been drawn by the painter's brush or a grainer. The top of this layer is somewhat conglomerate, small masses of clay being mixed with the sand.

The pebbles of No. 2 are more numerous at the top. No. 3 appears to be a weathered product of No. 2. If Nos. 1 and 2 are Lafayette, as seems probable, then No. 3 doubtless represents the Columbia.

PLATE XXXV.



A. CLAY PARTINGS IN LAFAYETTE SANDS, NEWTON.



B. EROSION IN LAFAYETTE SANDS BY UNDERGROUND WATER, NEWTON.

TABLE 80.

ANALYSES OF CLAYS, NEWTON.

	No. 91	*No.* 92
Moisture (H_2O)	1.52	2.32
Volatile matter (CO_2 etc.)	3.08	3.20
Silicon dioxide (SiO_2)	84.54	82.82
Iron oxide (Fe_2O_3)	4.12	3.75
Aluminum oxide (Al_2O_3)	.60	7.05
Calcium oxide (CaO)	5.83	.50
Magnesium oxide (MgO)	.22	.17
Sulphur trioxide (SO_3)	.23	.00
Total	100.14	99.41

RATIONAL ANALYSIS.

Clay substance	1.50	17.83
Free silica	83.63	71.54
Impurities	10.40	4.42

No. 91 is from the Hancock pit; No. 92 is from an outcrop ½ mile west. The physical properties of No. 91 are: Water required for plasticity, 20 per cent; total shrinkage, 10 per cent; tensile strength of raw clay, 87 pounds per square inch; burned, 150 pounds per square inch. No. 92 has the following physical properties: Total shrinkage, 1 per cent; water required for plasticity, 17 per cent; tensile strength, raw, 37 pounds; burned, 53 pounds per square inch. It is deficient in bonding matter.

NOXUBEE COUNTY.

GEOLOGY.

The subsurface of Noxubee County is the Selma and the Ripley divisions of the Cretaceous, and the Wilcox. The surficial formations are isolated outcrops of the Lafayette, the Columbia and the residual Selma clays.

CLAY INDUSTRY.

Macon.—The surface clays are used at Macon by the Cline Brick Manufacturing Company in the manufacture of brick by the soft-mud process. The clay is tempered in a ring pit. The brick are molded by hand and burned in rectangular up-draft kilns. In the clay pit, about 8 feet of clay rests upon the Selma chalk. The clay in the upper portion of the bed is red in color and of a coarse, sandy texture. It is probably Lafayette. The lower portion of the clay is

more plastic and cannot be used alone on account of sticking in molds in molding, and of checking and cracking in drying.

The Selma chalk contains concretions of iron pyrites which, upon exposure to the atmosphere, oxidize producing ferrous sulphate and sulphuric acid which act upon the limestone. The limestone being dissolved, the insoluble clay which it contains is left behind, and accumulates to form a thick bed. The clay immediately overlying the limestone is greenish in color, a condition probably due to the presence of ferrous sulphate. Concretions of iron oxide also occur along the line of contact between the clay and the limestone. These are formed by the oxidation of the iron pyrites nodules.

The following analyses are of two samples of the Selma chalk from Macon:

TABLE 81.

ANALYSES OF SELMA LIMESTONES No. 100, MACON.

	No. 1	*No.* 2
Moisture (H_2O)	1.25	.95
Volatile matter (CO_2 etc.)	36.28	35.15
Silicon dioxide (SiO_2)	9.18	13.03
Aluminum oxide (Al_2O_3)	.00	5.25
Iron oxide (Fe_2O_3)	3.50	2.18
Calcium oxide (CaO)	45.92	41.56
Magnesium oxide (MgO)	.84	.36
Sulphur trioxide (SO_3)	.34	.64
Total	97.31	99.12

No. 2 was collected by A. F. Crider from Macon Bluff on the Tombigbee River.

The greenish colored clay overlying the limestone has the following chemical constituents:

TABLE 82.

ANALYSIS OF RESIDUAL SELMA CLAY, MACON.

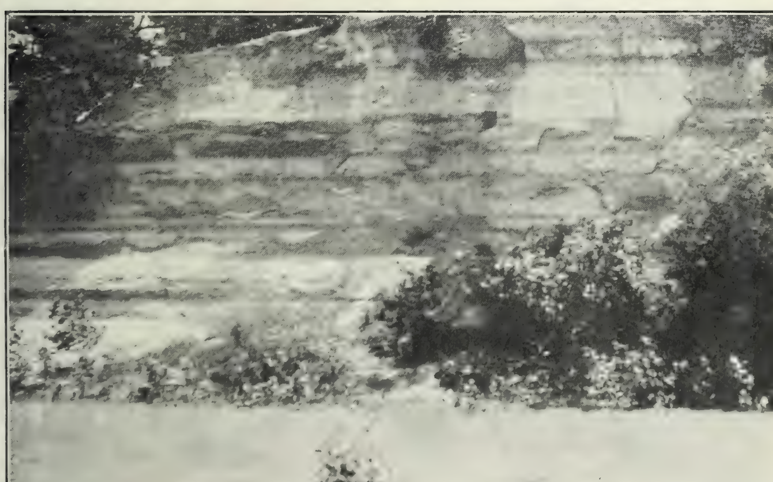
	No. 101
Moisture (H_2O)	11.60
Volatile matter (CO_2 etc.)	10.00
Silicon dioxide (SiO_2)	50.51
Aluminum oxide (Al_2O_3)	17.31
Iron oxide (Fe_2O_3)	5.75
Calcium oxide (CaO)	2.70
Magnesium oxide (MgO)	1.40
Sulphur trioxide (SO_3)	.21
Total	99.48

RATIONAL ANALYSIS.

Clay substance	43.79
Free silica	30.16
Impurities	10.06

PLATE XXXVI.

A. RESIDUAL CLAY AND LAFAYETTE OVERLYING SELMA CHALK, MACON.



B. SELMA CHALK ON NOXUBEE RIVER, MACON.

There is but little doubt that the above mentioned clay has been derived from the Selma limestone, the decomposition of which was influenced by the decomposition of the iron pyrites present in the limestone. This bottom clay is too fat to be used in the manufacture of brick. It sticks to the molds when used in the soft-mud machine and cracks in drying when used in the stiff-mud machine. The Lafayette clay lying above the residual Selma is much leaner and contains a high per cent of iron. The chemical analysis of the Lafayette clay from Macon follows:

TABLE 83.

ANALYSIS OF CLAY, MACON.

	No. 77
Moisture (H_2O)	7.59
Volatile matter (CO_2 etc.)	7.75
Silicon dioxide (SiO_2)	57.25
Iron oxide (Fe_2O_3)	18.95
Aluminum oxide (Al_2O_3)	6.17
Calcium oxide (CaO)	1.05
Magnesium oxide (MgO)	.95
Sulphur trioxide (SO_3)	.21
Total	99.92

RATIONAL ANALYSIS.

Clay substance	15.61
Free silica	50.00
Impurities	27.16

In the manufacture of brick the best results are to be obtained by mixing the Lafayette clay with the Selma residual clay. Near the railroad station at Macon there is a residual clay which is probably derived from the Flatwoods clay. The grain of the clay is fine and it has shrinkage of 15 per cent. The tensile strength of the raw clay is 87 pounds; the burned clay has a strength of 78 pounds; the water required for plasticity is 18 per cent; the amount of absorption of the burned clay is 8.69 per cent. The absorption of the Lafayette clay is 11.42 per cent.

OKTIBBEHA COUNTY.

GEOLOGY.

The bed-rock formations of Oktibbeha County belong to the Cretaceous and the Tertiary periods. The Selma chalk and a few outliers of the Ripley are present in the eastern part of the county. The western part of the county is underlain by the Wilcox-Eocene. The mantle deposits are Lafayette, residual Selma and Columbia. The last two are well represented in the western part of the county, but only by isolated outcrops in the eastern half. The residual Selma clay and the Columbia are used in the manufacture of brick in Starkville.

CLAY INDUSTRY.

Starkville.—At Starkville the Howard Brick Manufacturing Company uses a clay which rests directly upon the surface of the Selma chalk. The greater part of the clay deposit was formed doubtless by the decomposition of the limestone. The limestone immediately below the clay is partly decomposed and contains 19.30 per cent of clay. The following analyses show the composition of the limestone and the clay immediately above:

TABLE 84.

ANALYSES OF LIMESTONE AND CLAY, STARKVILLE.

	No. 40	*No.* 41
Moisture (H_2O)	.85	4.75
Volatile matter (CO_2 etc.)	23.15	2.27
Silicon dioxide (SiO_2)	20.60	65.30
Iron oxide (Fe_2O_3)	4.62	12.18
Aluminum oxide (Al_2O_3)	7.63	12.63
Calcium oxide (CaO)	41.81	1.50
Magnesium oxide (MgO)	.81	.63
Sulphur trioxide (SO_2)	.25	.25
Total	99.72	99.51

RATIONAL ANALYSIS.

Clay substance	19.30	31.95
Free silica	11.73	51.45
Impurities	47.49	14.18

No. 40—Selma limestone.
No. 41—Residual Selma clay.

Samples of clay and limestone taken from another part of the pit have the following composition:

TABLE 85.

ANALYSES OF SELMA LIMESTONE AND OVERLYING CLAY, STARKVILLE.

	No. 9	*No.* 10
Moisture (H_2O)	.75	.55
Volatile matter (CO_2)	28.20	.97
Silicon dioxide (SiO_2)	17.03	76.60
Iron oxide (Fe_2O_3)	3.33	2.00
Aluminum oxide (Al_2O_3)	21.00	18.37
Calcium oxide (CaO)	29.29	.90
Magnesium oxide (MgO)	.00	.00
Sulphur trioxide (SO_3)	.72	.70
Potassium oxide (K_2O)	.00	.00
Sodium oxide (Na_2O)	.00	.00
Total	100.32	100.09

RATIONAL ANALYSIS.

Clay substance	53.13	46.47
Free silica	7.66	55.00
Impurities	33.34	3.60

No. 9—Selma limestone.
No. 10—Residual Selma clay.

The sample of limestone was taken from immediately below the clay. It contains 53.13 per cent of clay substance, or is more than half clay. The clay sample was from near the bottom of the clay deposit. The bottom clay is usually too plastic, and has too high a shrinkage to be used alone in the manufacture of brick. The proper texture and shrinkage is obtained by mixing the more sandy top clay with the bottom clay. The top clay contains considerable non-plastic material. The clay immediately overlying the limestone requires careful selection to prevent defects in the brick, because it contains in places nodules or concretions of limestone and ironstone. These nodules are liable to break the wires of the cutter, and to produce cavities or fused masses in the brick. The limestone nodules represent the more insoluble portions of the chalk, such as the casts of shells and the concretions of which fossils form the nuclei. The iron nodules were formed doubtless by the oxidation of concretionary nodules of iron pyrites, which are not of uncommon occurrence in the chalk.

The oxidation of the pyrite produces sulphuric acid, which attacks the calcium carbonate, forming calcium sulphate (gypsum), which is soluble in water and thus may be dissolved out as the clay weathers. The chemical reaction is as follows:*

$$FeS_2 + 60 = FeSO_4 + SO_2 \text{ or}$$
$$FeS_2 + 30 = H_2O + FeSO_4 + H_2S$$

*Van Hise, Metamorphism, p. 214.

The iron sulphate ($FeSO_4$) may be changed to iron oxide, limonite, by oxidation and hydration:

$$FeSO_4 + 2O + 7H_2O = 2Fe_2O_3 + 3H_2O + 4H_2SO_4$$

The sulphuric acid (H_2SO_4) then reacts with the calcium carbonate to produce calcium sulphate:

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$$

or the iron sulphate may react directly in the following manner:

$$FeSO_4 + CaCO_3 = CaSO_4 + FeCO_3$$

The sulphuric acid, together with the action of the acids produced by decaying vegetation, dissolve out the limestone and cause the accumulation of the insoluble clay residue.

Agricultural and Mechanical College.—The residual Selma clay also occurs on the campus of the State Agricultural and Mechanical College. From an excavation made during the construction of the steam pipe tunnel, the following samples were taken from a point immediately in front of the Mess Hall. The analyses of these samples are recorded below:

TABLE 86.

ANALYSES OF LIMESTONE AND CLAYS, AGRICULTURAL COLLEGE.

	No. 64	*No.* 65	*No.* 66	*No.* 67	*No.* 68	*No.* 69
Moisture (H_2O)	1.50	6.02	5.50	5.00	4.46	5.36
Volatile matter (CO_2)	24.50	6.50	5.00	4.35	5.65	2.78
Silicon dioxide (SiO_2)	29.98	63.35	67.60	69.35	66.85	66.51
Aluminum oxide (Al_2O_3)	5.60	13.70	12.55	12.65	12.05	15.10
Iron oxide (Fe_2O_3)	5.45	7.90	7.60	6.80	7.07	7.00
Calcium oxide (CaO)	31.62	.80	.80	.50	1.62	1.00
Magnesium oxide (MgO)	.14	.60	.78	.58	.18	.58
Sulphur trioxide (SO_3)	.21	.34	.17	.42	.08	.31
Total	99.00	99.21	100.00	99.65	97.96	98.64

RATIONAL ANALYSIS.

Clay substance	14.16	34.66	31.75	32.00	30.48	38.20
Free silica	23.40	47.24	43.85	54.48	48.42	48.76
Impurities	37.42	9.64	9.35	8.30	8.95	8.89

No. 64 is the limestone or chalk immediately underlying the clay. Nos. 65 to 69, inclusive, are samples of clay from the tunnel taken in order from bottom to top of the first 5 feet of clay, one sample being taken from each successive foot. The absorption of No. 64 is 18 per cent. Clay No. 65 has a total shrinkage of 8 per cent; it requires 16 per cent of water for plasticity; it has a tensile strength, raw, of 133 pounds per square inch, and when burned has a strength of 146

pounds per square inch. It loses 12 per cent in weight in being burned, and has an absorption of 7.27 per cent. When mixed with 10 per cent of coal it requires 14 per cent of water to render it plastic. The loss of weight in the soft-burned brickettes is 15 per cent. It has a total shrinkage of 3⅓ per cent. The tensile strength of the raw clay is 119 pounds per square inch. When burned it has a strength of 150 pounds per square inch. Its absorption is 12.24 per cent. When mixed with 10 per cent of cinders the clay has a total shrinkage of 3⅓ per cent; requires 15 per cent of water for plasticity; has a tensile strength, raw, of 72 pounds per square inch, and when burned a strength of 153 pounds per square inch. Its loss of weight in burning is 14 per cent. Its absorption is 12.9 per cent.

Clay No. 66 has a total shrinkage of 6 per cent. It requires 15 per cent of water for plasticity. The loss in burning is 12 per cent. The tensile strength of the raw clay is 94 pounds per square inch. When burned it has a strength of 250 pounds per square inch. Its absorption is 9.8 per cent.

Clay No. 67 has a total shrinkage of 5½ per cent. It requires 14 per cent of water for plasticity. The loss of weight in burning is 14 per cent. The raw clay has a tensile strength of 94 pounds per square inch and when burned its strength is 240 pounds per square inch. Its absorption is 9.4 per cent. When mixed with 10 per cent of coal the clay requires 16 per cent of water; shrinks 3⅓ per cent; has a tensile strength, raw, of 77 pounds and soft-burned of 106 pounds per square inch. When mixed with 10 per cent of cinders it requires 14 per cent of water; has a total shrinkage of 3⅓ per cent. The raw clay has a strength of 66 pounds and the burned clay a strength of 131 pounds per square inch. Its absorption is 15.09 per cent.

Clay No. 68 requires 16 per cent of water; it has a total shrinkage of 5 per cent; its loss of weight in burning is 13 per cent; its tensile strength, raw, is 133 pounds per square inch. When burned it has a strength of 312 pounds per square inch. Its absorption is 9.61 per cent.

Clay No. 69 requires 17 per cent of water for plasticity. The total shrinkage of the clay is 5 per cent. The tensile strength of the raw clay is 105 pounds per square inch. The strength of the burned clay is 333 pounds per square inch. Its absorption is 13.55 per cent. The average absorption of all except No. 64 is 10.12 per cent.

In an excavation for a sewer line a few rods south of the above mentioned tunnel, a bed of clay was exposed resting upon the surface of the chalk. A sample of the chalk and one sample from the bottom and one sample from the middle of the clay deposit were taken and analyzed with the following results:

TABLE 87.

ANALYSES OF LIMESTONE AND CLAYS, AGRICULTURAL COLLEGE.

	No. 35	*No.* 36	*No.* 37
Moisture (H_2O)	.81	4.06	2.95
Volatile matter (CO_2 etc.)	28.61	8.60	10.90
Silica (SiO_2)	27.05	60.43	56.97
Iron oxide (Fe_2O_3)	5.45	10.05	10.40
Aluminum oxide (Al_2O_3)	6.45	13.15	15.09
Calcium oxide (CaO)	30.21	2.13	1.00
Magnesium oxide (MgO)	.00	.54	1.25
Sulphur trioxide (SO_3)	.32	.36	.34
Total	98.90	99.32	98.90

RATIONAL ANALYSIS.

Clay substance	16.31	33.26	38.17
Free silica	20.47	45.97	39.23
Impurities	35.93	12.08	12.99

No. 35—Selma chalk.

Nos. 36 and 37—Residual Selma clays.

Maben.—The Maben Brick Manufacturing Company, of Maben, began the manufacture of brick in 1905. Two kinds of clay are used. One kind is a white clay from the B. F. Sanders farm, a few miles west of Maben. The clay belongs to the Wilcox (Lagrange) division of the Lignitic. It remains white when burned. Its shrinkage is very low. The chemical composition of a sample is given below:

TABLE 88.

ANALYSIS OF WHITE CLAY, MABEN.

	No. 59*a*
Moisture (H_2O)	1.47
Volatile matter (CO_2 etc.)	9.24
Silica (SiO_2)	59.82
Iron oxide (Fe_2O_3)	1.26
Aluminum oxide (Al_2O_3)	27.19
Calcium oxide (CaO)	.49
Magnesium oxide (MgO)	.37
Sulphur trioxide (SO_3)	.31
Total	100.15

RATIONAL ANALYSIS.

Clay substance	68.80
Free silica	18.21
Impurities	2.43

The above mentioned plant also uses a surface clay belonging to the yellow loam phase of the Columbia. The clay pit has the following stratigraphy:

Section of Clay Pit, Maben.

	Feet
2. Sandy loam, gray to yellow........................	2
1. Clay, gray in color................................	6

In the bottom of the pit there are numerous ironstone concretions.

The brick burned from the surface clay vary in color from bright red to chocolate. They are molded in a stiff-mud machine of the auger type. The clay is prepared in a granulator and disintegrator and tempered in a horizontal pug mill. The brick are burned in rectangular up-draft clamp kilns. The brick are dried by being packed on pallets and placed on racks in covered sheds.

PANOLA COUNTY.

GEOLOGY.

The Wilcox forms the subsurface of Panola County. The mantle rocks consist of the alluvial deposits of the Yazoo basin, the Loess, the Lafayette and the Columbia. The clay from the last named formation is used in the manufacture of brick.

CLAY INDUSTRY.

Sardis.—At Sardis the clay from the Columbia is employed in the manufacture of brick by the Buchanan Brick Manufacturing Company. The brick are molded by the soft-mud process. The clay is prepared in a disintegrator and tempered in a pug mill. It is then molded in a soft-mud machine which is operated by steam power. The brick are burned in rectangular up-draft kilns.

The clay in the pit has a thickness of 8 to 10 feet. The upper portion is much leaner than the basal portion. The following analysis gives the composition of the latter:

TABLE 89.

ANALYSIS OF COLUMBIA CLAY, SARDIS.	*No.* 80
Moisture (H_2O)	2.90
Volatile matter (CO_2 etc.)	2.42
Silicon dioxide (SiO_2)	74.41
Iron oxide (Fe_2O_3)	5.37
Aluminum oxide (Al_2O_3)	12.22
Calcium oxide (CaO)	1.40
Magnesium oxide (MgO)	1.25
Sulphur trioxide (SO_3)	.03
Total	100.00

RATIONAL ANALYSIS.	
Clay substance	30.91
Free silica	60.04
Impurities	8.05

The physical properties of the Sardis clay are as follows: The clay requires 18 per cent of water to render it plastic. It has a total shrinkage of 6 per cent. The raw brickettes show a tensile strength of 111 pounds per square inch, and when burned they have a strength of 140 pounds per square inch. The loss in burning is 5 per cent of the weight and the absorbtive power of the burned clay is 14.51 per cent. The minimum amount of bonding power is exhibited by the clay from the upper portion of the pit. The basal clay requires the addition of non-plastic material for the manufacture of soft-mud brick.

Batesville.—No brick are being manufactured at Batesville at present. No doubt the Brown loam clays which are well represented there could be utilized with the same degree of success that has been attained in other parts of the county. The unweathered Loess which lies at the base of the Columbia cannot be used alone in the manufacture of brick. It lacks bonding power. The following analysis is of a sample of unweathered, or but slightly weathered, Loess from Batesville.

TABLE 90.

ANALYSIS OF UNWEATHERED LOESS, BATESVILLE.	*No.* 78
Moisture (H_2O)	1.81
Volatile matter (CO_2)	3.20
Silicon dioxide (SiO_2)	75.11
Iron oxide (Fe_2O_3)	5.50
Aluminum oxide (Al_2O_3)	10.70
Calcium oxide (CaO)	.60
Magnesium oxide (MgO)	.47
Sulphur trioxide (SO_3)	.00
Total	97.39

RATIONAL ANALYSIS.

Clay substance	27.07
Free silica	62.53
Impurities	6.57

The aluminum in analysis No. 78 is probably largely contained in undecomposed feldspars. This fact undoubtedly accounts for the low bonding power of the clay. The best residual clays from this formation are to be found in areas where the Loess has not been subjected to rapid erosion. Second bottom deposits usually afford the best clays.

The physical properties of the above mentioned Loess clay are as follows: It requires 18 per cent of water for plasticity. The air shrinkage is 4 per cent. The raw clay has a maximum tensile strength of 72 pounds per square inch, and the hard-burned brickettes show a maximum strength of 111 pounds per square inch. The color of the burned clay is red. The clay cracks badly when dried rapidly and is deficient in bonding power.

PONTOTOC COUNTY.

GEOLOGY.

Pontotoc County is crossed from north to south by the following formations, taking them in order from east to west: Selma chalk, Ripley and Wilcox. The surficial formations belong to the Lafayette and the Columbia.

CLAY INDUSTRY.

Pontotoc.—The Columbia clay is used at Pontotoc in the manufacture of brick. The plant is operated by the Austin Brick Manufacturing Company. The following is an analysis of a sample of the clay used:

TABLE 91.

ANALYSIS OF COLUMBIA CLAY, PONTOTOC.

	No. 105
Moisture (H_2O)	2.13
Volatile matter (CO_2 etc.)	3.70
Silicon dioxide (SiO_2)	77.57
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	7.25
Calcium oxide (CaO)	.50
Magnesium oxide (MgO)	1.90
Sulphur trioxide (SO_3)	.17
Total	99.47

RATIONAL ANALYSIS.

Clay substance	18.34
Free silica	69.05
Impurities	8.82

Clay No. 105 has an absorption of 12.96 per cent. Its total shrinkage is 6⅝ per cent. It requires 15 per cent of water for plasticity. The tensile strength of the raw clay is 60 pounds per square inch, and of the burned clay 80 pounds per square inch.

PRENTISS COUNTY.

GEOLOGY.

The Subcarboniferous forms the bed-rock of a small part of the southeastern portion of Prentiss County. The Tuscaloosa clays outcrop along the eastern part of the county. The central portion is occupied by the Eutaw formation, and the western portion, with the exception of the northwestern corner, by the Selma chalk. The Ripley occupies a small area west of the Selma. The mantle rock formations are the residual clays of these various bed-rocks, the Lafayette and the Columbia loams. The clays of these surface formations are being used in the manufacture of brick and tile at Booneville and at Thrasher.

CLAY INDUSTRY.

Booneville.—The Booneville Brick and Tile Company of Booneville use the clay from a pit in which the following stratigraphy is revealed:

Section of Clay Pit at Booneville.

	Feet
4. Sandy loam (Columbia)	2–3
3. Reddish clay	3–5
2. Bluish clay	4
1. White chalk containing shells	...

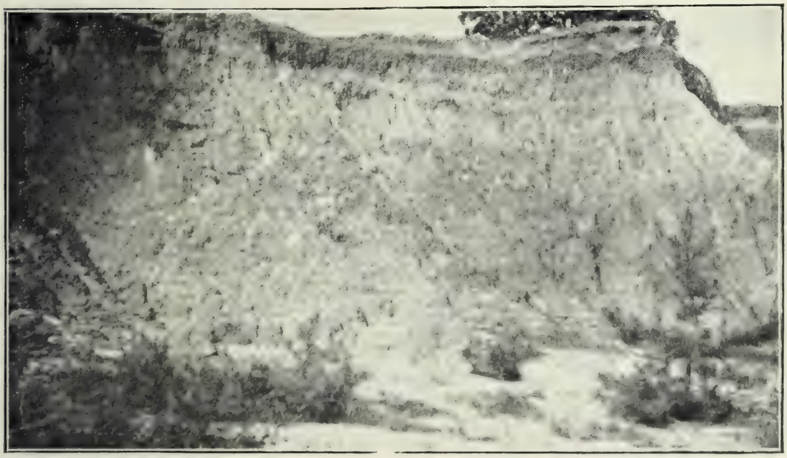
A little higher up the clay has a greater thickness, as the record of Mr. H. T. Turkett's well seems to indicate.

Turkett Well Record, Booneville.

	Feet
1. Yellow and blue clay	20
2. Blue limestone	20
3. Water-bearing sand	5

PLATE XXXVII.

A. RESISTANT LAYER IN THE COLUMBIA LOAM, BRANDON.



B. LAFAYETTE SANDS, BRANDON THE RED SAND OF THE OUTCROP WEATHERED WHITE IN THE FLAT BELOW.

Clay No. 2 of the pit section has the maximum shrinkage when hard burned, and No. 4 the minimum shrinkage. The brick shrink about ½ inch in length and ¼ inch in width. A mixture of these clays is used in the manufacture of brick and tile. In drying the brick, care must be exercised to prevent the currents of air from striking the brick too soon after they are brought from the machine. Too rapid drying at first causes cracking and checking. Because of the presence of lime and ironstone concretions in some parts of these clays, care must also be exercised in burning to prevent fusion in some parts of the kiln before the brick in the other parts have reached the proper hardness. The lime acts as a flux to melt the iron. This action runs the brick together in a slaggy mass. The ends of the eye-brick are usually glazed by this reducing action of the lime. No granulator, disintegrator or pug mill is used in preparing and tempering the clay. It is molded in a stiff-mud side-cut machine. The brick and tile are burned in rectangular up-draft kilns of the clamp type. The company also manufactures some drain tile each year.

Thrasher.—At Thrasher, the Thrasher Brick Manufacturing Company opened a yard for the manufacture of brick in 1906. The clay used is a surface clay, probably of Columbia age. Its prevailing color is yellow. The brick are molded in a stiff-mud machine of the plunger type. They are burned in rectangular up-draft kilns.

RANKIN COUNTY.

GEOLOGY.

The subsurface of Rankin County is occupied by Tertiary strata belonging to the Jackson, Vicksburg and Grand Gulf groups. The surficial formations are the Lafayette and the Columbia.

CLAY INDUSTRY.

Brandon.—The Columbia has been used at Brandon in the manufacture of brick by the soft-mud process. One plant was located southeast of town and another across from the Alabama and Vicksburg station, northeast of town. Neither of these plants is in operation at present.

On the slope of the hill above the Alabama and Vicksburg station there is an exposure of Lafayette clay which has the following composition:

TABLE 92.

ANALYSIS OF COLUMBIA CLAY, BRANDON.

	No. 74
Moisture (H_2O)	4.89
Volatile matter (CO_2 etc.)	4.86
Silicon dioxide (SiO_2)	75.16
Iron oxide (Fe_2O_3)	5.77
Aluminum oxide (Al_2O_3)	7.75
Calcium oxide (CaO)	.62
Magnesium oxide (MgO)	.87
Sulphur trioxide (SO_3)	.00
Total	99.92

RATIONAL ANALYSIS.

Clay substance	19.60
Free silica	66.05
Impurities	7.26

At the foot of the hill, east of the station at Brandon, there is an outcrop of white Vicksburg limestone. South of the station at a little higher level is a marl which is highly fossiliferous. The section exposed is as follows:

Section South of the Railroad Station, Brandon.

	Feet
4. Brownish loam	5
3. Red to purple clay	4
2. Yellow clay	1
1. Marl containing shells	6

Layers 2 and 3 are residual clays formed by the decomposition of the marl.

In an abandoned railroad cut, at the top of the divide upon which Brandon is located, there is an outcrop of Lafayette sand capped by a layer of light brown loam. The Lafayette, in places, weathers to a white sand. The grains of sand are coarse and mostly fragments of transparent quartz crystals. Some of the grains are opaque white. About 25 feet of this sand is exposed. Farther west, the sand has partings of white clay at its base. Above the red sand there is a foot or two of lighter colored transition loam, then about one foot of hard, indurated resistant loam. So indurated is the layer that on an exposed surface it projects from the face of the exposure, and when

Plate XXXVIII.

A. TERRACE IN THE LOESS AT THE NATIONAL CEMETERY VICKSBURG.

B. VICKSBURG LIMESTONE, NEAR BRANDON.

broken up forms a sort of gravel. In places it serves as a sort of capping to protect the softer underlying rocks and thus produces a variety of small topographic forms. Above the indurated layer there is an exposure of about 4 feet of brown loam covered by a foot or more of soil. A sample of clay from the indurated portion has the following chemical composition:

TABLE 93.

ANALYSIS OF COLUMBIA CLAY, BRANDON.

	No. 75
Moisture (H_2O)	1.56
Volatile matter (CO_2 etc.)	2.65
Silicon dioxide (SiO_2)	82.32
Iron oxide (Fe_2O_3)	5.77
Aluminum oxide (Al_2O_3)	5.17
Calcium oxide (CaO)	.50
Magnesium oxide (MgO)	.91
Sulphur trioxide (SO_3)	.09
Total	98.97

RATIONAL ANALYSIS.

Clay substance	13.08
Free silica	76.25
Impurities	7.27

The cementing substance in the hard layer mentioned above is undoubtedly silica. The amount of iron and of calcium carbonate does not seem adequate to form such a degree of induration.

Rankin State Farm.—In an attempt to find a clay suitable for the manufacture of brick on the State farm in Rankin County the writer collected a number of samples. A chemical analysis of one of these samples was made with the following results:

TABLE 94.

ANALYSIS OF CLAY, RANKIN COUNTY STATE FARM.

	No. 71
Moisture (H_2O)	.81
Volatile matter (CO_2 etc.)	9.20
Silicon dioxide (SiO_2)	81.72
Iron oxide (Fe_2O_3)	4.81
Aluminum oxide (Al_2O_3)	.86
Calcium oxide (CaO)	.62
Magnesium oxide (MgO)	.89
Sulphur trioxide (SO_3)	.36
Total	99.27

RATIONAL ANALYSIS.

Clay substance	2.17
Free silica	80.71
Impurities	6.58

The absorption of clay No. 71 is 14.94 per cent. It contained such a small amount of clay substance that it was deficient in bonding power. It is about four-fifths sand and contains more than 6 per cent of fluxing impurities.

SCOTT COUNTY.

GEOLOGY.

The substrata of Scott County belong to the Claiborne, Jackson and Vicksburg. The Lafayette and Columbia form the surficial formations. There are also some residual clays formed from the Jackson marls.

CLAY INDUSTRY.

Forest.—At Forest, a residual Jackson clay outcrops in a small ravine in the western part of the town. The analysis of this clay is given in No. 113, below:

TABLE 95.

ANALYSES OF CLAYS, FOREST

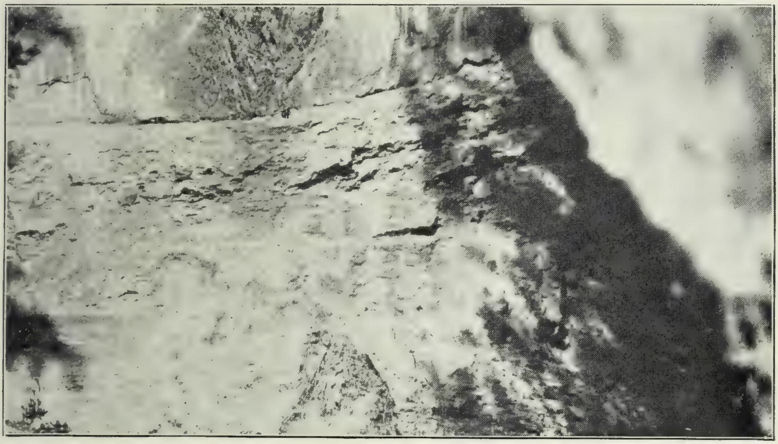
	No. 113	*No.* 112
Moisture (H_2O)	5.05	1.80
Volatile matter (CO_2 etc.)	6.41	2.48
Silicon dioxide (SiO_2)	69.01	86.38
Iron oxide (Fe_2O_3)	8.02	2.82
Aluminum oxide (Al_2O_3)	5.60	1.23
Calcium oxide (CaO)	2.50	4.17
Magnesium oxide (MgO)	.48	.27
Sulphur trioxide (SO_3)	.51	.02
Total	98.58	99.17

RATIONAL ANALYSIS.

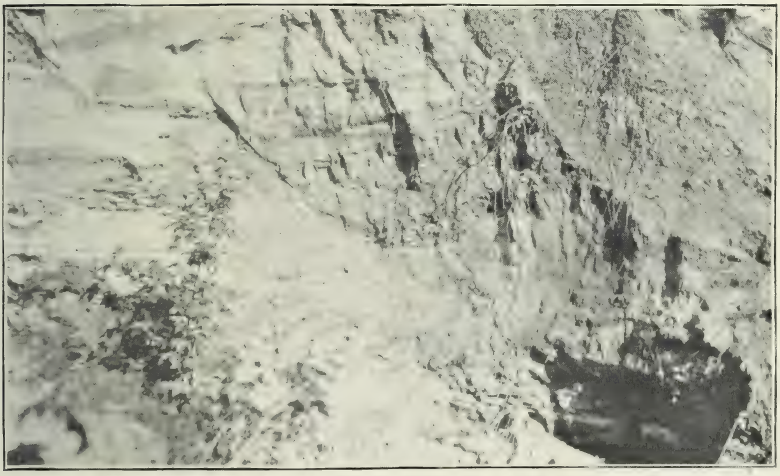
Clay substance	20.29	3.11
Free silica	56.74	84.50
Impurities	10.19	7.28

A sample of clay taken from a railroad cut near the station belongs to a surface loam. The deposit contains some pebbles at the base and the clay has some small gravels. It is probably Lafayette or Columbia. The composition of a sample is given in No. 112 of the above table. The burned brickettes have an absorption of 9.02 per cent.

PLATE XXXIX.



A. LIGNITIC STRATUM IN THE JACKSON SANDS, MORTON.



B. LOCAL FAULT IN THE JACKSON STRATA, MORTON.

Morton.—In the southern part of the town of Morton there is an outcrop of Jackson which has the following stratigraphy (see Plate XXXIX, *A*):

Section of the Jackson, Morton.

	Feet
3. Grayish clay in thin layers	5
2. Lignite and lignitic clay	6
1. White sand, cross bedded with clay partings	15

In another outcrop southeast of the above mentioned point, there are exposed about 6 feet of grayish sticky clay which has resting upon it an alternating bed of clay and sand with a thickness of 20 feet. At one place in this outcrop a fault having a throw of 4 feet is visible. (See Plate XXXIX, *B*.) The grayish clay has the following chemical composition:

TABLE 96.

ANALYSIS OF JACKSON CLAY, MORTON.

	No. 90
Moisture (H_2O)	7.35
Volatile matter (CO_2 etc.)	10.12
Silicon dioxide (SiO_2)	61.82
Iron oxide (Fe_2O_3)	2.80
Aluminum oxide (Al_2O_3)	12.28
Calcium oxide (CaO)	.82
Magnesium oxide (MgO)	.54
Sulphur trioxide (SO_3)	.04
Total	95.77

RATIONAL ANALYSIS.

Clay substance	31.06
Free silica	43.04
Impurities	4.20

Clay No. 90 requires 22 per cent of water for plasticity; has a tensile strength, raw, of 81 pounds per square inch; burned, 131 pounds per square inch; has a total shrinkage of 10 per cent; and has an absorption of 11.11 per cent. Mixed with 10 per cent coal it has a total shrinkage of 7 per cent; has a tensile strength, raw, of 100 pounds; and has a tensile strength, burned, of 233 pounds per square inch. When mixed with 10 per cent cinders its total shrinkage is 7 per cent; its tensile strength, raw, is 100 pounds, and burned is 235 pounds per square inch.

SUNFLOWER COUNTY.

GEOLOGY.

Sunflower County lies within the Yazoo basin and its entire surface formation is alluvium. Sandy loams and stiff black clays form the surface. Underlying the alluvial deposit are the clays, sands and sandstones of the Claiborne and Wilcox.

CLAY INDUSTRY.

Indianola.—The alluvial clays are being used at Indianola in the manufacture of brick. Two plants are in operation at this point; both of them use the dry-press process of manufacture.

In the pit used by the Indianola Brick and Tile Company the following strata are exposed:

Section of Clay Pit, Indianola.

	Feet
3. Yellowish loam	3
2. Dark colored clay (buckshot)	2
1. Yellowish clay	6

A sample of No. 1 was taken for analysis with the following result:

TABLE 97.

ANALYSIS OF ALLUVIAL CLAY INDIANOLA.

	No. 54
Moisture (H_2O)	5.00
Volatile matter (CO_2 etc.)	7.57
Silicon dioxide (SiO_2)	60.00
Iron oxide (Fe_2O_3)	4.62
Aluminum oxide (Al_2O_3)	20.00
Calcium oxide (CaO)	.80
Magnesium oxide (MgO)	.47
Sulphur trioxide (SO_3)	.85
Total	99.31

RATIONAL ANALYSIS.

Clay substance	50.60
Free silica	36.48
Impurities	6.74

Clay No. 54 requires 20 per cent of water to render it plastic. It loses 13 per cent in weight in burning. In the raw state its tensile strength is 262 pounds. The burned brickettes have a strength of

390 pounds. It burns to a red color but fuses at a moderately low temperature. Great care must be exercised in drying and burning to prevent cracking and swelling. The stratum is not used alone but is mixed with the overlying leaner clay, and more satisfactory results are obtained. The effect of the top clay is to facilitate drying and lessen shrinkage. When burned hard the center of the bricks are steel blue in color. The hard-burned bricks have a water absorption of 9.3 per cent.

The Sunflower Brick Manufacturing Company also operates a plant at Indianola. The plant is located on the line of the Southern Railway, west of town. The pit as far as opened at the time of the visit of the writer exhibited the following:

Section of Clay Pit, Indianola.

	Feet
2. Light grayish, loamy clay	3
1. Dark colored clay	6

Samples of clay were taken from both of these layers. The analyses are given below. Analysis No. 52 was made from layer No. 1 and No. 53 from layer No. 2.

TABLE 98.

ANALYSES OF BRICK CLAYS, INDIANOLA.

	No. 52	*No.* 53
Moisture (H_2O)	7.27	2.15
Volatile matter (CO_2 etc.)	2.40	4.85
Silicon dioxide (SiO_2)	71.17	71.67
Iron oxide (Fe_2O_3)	6.04	7.90
Aluminum oxide (Al_2O_3)	10.06	8.10
Calcium oxide (CaO)	1.00	.90
Magnesium oxide (MgO)	1.16	.94
Sulphur trioxide (SO_3)	.48	.62
Total	99.58	97.13

RATIONAL ANALYSIS.

Clay substance	25.47	20.49
Free silica	11.83	62.15
Impurities	8.68	10.36

Brickettes of clay No. 52 lose 14 per cent in weight in being burned. The clay becomes plastic when mixed with 22 per cent of water. It has a total shrinkage of 10 per cent. The tensile strength of the raw clay is 300 pounds.

Clay No. 53 is rendered plastic by the addition of 20 per cent of water. The air shrinkage is about 5 per cent. The tensile strength of the raw clay is 100 pounds. The burned brickettes have a strength of 300 pounds per square inch.

Moorhead.—A sample of alluvium clay of the plastic "buckshot" type was collected near the plant of the Moorhead Manufacturing Company at Moorhead. The clay is bluish black in color and of very fine grain. The amount of water required to render it plastic is 25.89 per cent. In the raw state the clay has a tensile strength of 142 pounds. When burned hard it has a strength of 840 pounds. The total amount of shrinkage is 15 per cent. The chemical composition is given below:

TABLE 99.

ANALYSIS OF BUCKSHOT CLAY, MOORHEAD.

	No. 115
Moisture (H_2O)	7.20
Volatile matter (CO_2 etc.)	8.00
Silicon dioxide (SiO_2)	58.16
Iron oxide (Fe_2O_3)	4.95
Aluminum oxide (Al_2O_3)	17.25
Calcium oxide (CaO)	3.22
Magnesium oxide (MgO)	.27
Sulphur trioxide (SO_3)	.27
Total	99.32

RATIONAL ANALYSIS.

Clay substance	43.64
Free silica	31.77
Impurities	8.71

TATE COUNTY.

GEOLOGY.

The entire subsurface of Tate County is the Wilcox (Lagrange) division of the Tertiary. The mantle-rock formations are the Lafayette, the Loess, the Columbia and the Yazoo alluvium. The last two are the sources of the brick material.

CLAY INDUSTRY.

Senatobia.—The brown loam clay is used at Senatobia in the manufacture of brick. T. B. Montgomery and Son operate a plant at this point. The plant was established in 1900. The clay is tem-

pered in soak pits and molded in a soft-mud machine operated by horse power. The brick are placed upon pallets and racked in covered racks for drying. They are burned in up-draft kilns of the rectangular form. The local stratigraphy is disclosed by the well record at the plant:

Record of Montgomery Well.

	Thickness Feet	Depth Feet
4. Brown loam (Columbia)	12	12
3. Gravel (brown and white chert, Lafayette)	3	15
2. Red sandy clay	8	23
1. White sand, water-bearing	17	40

The brown loam and the underlying clay of the Columbia are well developed in Tate County. With the proper selection and mixing of the loam and clay a good quality of brick may be obtained.

TIPPAH COUNTY.

GEOLOGY.

The Ripley formation comprises the bed-rock of the eastern part of Tippah County, while the western part is underlain by the basal division of the Eocene. The mantle rock formations are the Lafayette sands and clays and the brown loam of the Columbia. The latter forms the chief source of brick clay under the present development.

CLAY INDUSTRY.

Ripley.—At Ripley the Ripley Brick Manufacturing Company uses a surface clay from the Columbia in the manufacture of brick. The stiff-mud, end-cut machine of the auger type is used. The brick are burned in rectangular up-draft kilns. From the clay pit and the well at the brick yard the following local stratigraphic conditions were determined:

Section of Clay Pit, Ripley.

	Feet
5. Soil	1
4. Loam	2
3. Brownish clay with buckshot at bottom	10
2. Sand (water-bearing)	1
1. Limestone with shells	2

All of the layers above No. 1 belong to the mantle rock. No. 1 belongs to the bed rock.

A sample of clay from No. 3 has the following chemical properties

TABLE 100.

ANALYSIS OF BRICK CLAY, RIPLEY.

	No. 110
Moisture (H_2O)	2.85
Volatile matter (CO_2 etc.)	2.80
Silicon dioxide (SiO_2)	82.20
Iron oxide (Fe_2O_3)	4.62
Aluminum oxide (Al_2O_3)	6.24
Calcium oxide (CaO)	1.05
Magnesium oxide (MgO)	.90
Sulphur trioxide (SO_3)	.04
Total	100.20

RATIONAL ANALYSIS.

Clay substance	15.78
Free silica	74.87
Impurities	6.61

The above mentioned clay requires 17 per cent of water to render it plastic. Its total shrinkage is 6 per cent. The tensile strength of the raw brickettes is 168 pounds per square inch. When soft burned the strength is 135 pounds per square inch. Air dried brick lose 2 per cent in weight in being dried at 100° F. and 5 per cent more in burning.

TUNICA COUNTY.

GEOLOGY.

Tunica County lies wholly within the Yazoo basin. Its surficial formation is the Post-Pleistocene alluvium. The bed rock formation probably belongs wholly to the Wilcox.

CLAY INDUSTRY.

Robinsonville.—The clays of the alluvial deposit are used at Robinsonville in the manufacture of brick and drain tile. The brick are molded in a machine of the stiff-mud type, and burned in a beehive kiln.

There are two principal types of the Yazoo alluvium in Tunica County. The sandy type, which is found near the streams, and the clayey interstream-area type. Because of the shifting of the streams or of temporary currents across the Yazoo basin during the building of the flood plain, both of these types may be found at the same place succeeding each other every few feet in a vertical section. These two types are mixed in the manufacture of brick and drain tile.

UNION COUNTY.

GEOLOGY.

The bed-rock formations of Union County are the Selma chalk and the Ripley in the eastern part, and the Wilcox in the western part. The mantle rock formations are the Lafayette and the Columbia. Pontotoc Ridge, which crosses the county from north to south about the central portion, exhibits the best development of the Lafayette. Clays from both the surficial formations are used in the manufacture of brick in this county.

CLAY INDUSTRY.

New Albany.—Two brick manufacturing plants are located at New Albany. The Butler Brick Manufacturing Company has a clay pit on the west side of a small ridge extending south of New Albany. The clay on the ridge is probably Lafayette, though the lower portion may be residual Ripley. The brick yard well pierced about 20 feet of this clay. The slopes of the Lafayette are covered with a mantle of brown loam, which increases in thickness toward the valley. The red-colored Lafayette clay is too sticky to be used in the soft-mud process of brick making. A sample of the Lafayette clay has the following chemical properties:

TABLE 101.

ANALYSIS OF LAFAYETTE CLAY, NEW ALBANY.

	No. 109
Moisture (H_2O)	2.27
Volatile matter (CO_2 etc.)	2.77
Silicon dioxide (SiO_2)	80.13
Iron oxide (Fe_2O_3)	4.62
Aluminum oxide (Al_2O_3)	9.00
Calcium oxide (CaO)	.25
Magnesium oxide (MgO)	.14
Sulphur trioxide (SO_3)	.09
Total	99.27

RATIONAL ANALYSIS.

Clay substance	22.77
Free silica	69.55
Impurities	5.10

The physical properties of clay No. 109 are as follows: It requires 17 per cent of water for plasticity. It has a total shrinkage of 5 per cent. Its tensile strength, raw, is 50 pounds per square inch.

The brown clay of the slope has been used by the above mentioned company in the manufacture of brick. The composition of this clay is given below:

TABLE 102.

ANALYSIS OF BRICK CLAY, NEW ALBANY.

	No. 108
Moisture (H_2O)	1.05
Volatile matter (CO_2 etc.)	2.85
Silicon dioxide (SiO_2)	85.24
Iron oxide (Fe_2O_3)	3.50
Aluminum oxide (Al_2O_3)	.71
Calcium oxide (CaO)	3.69
Magnesium oxide (MgO)	2.00
Sulphur trioxide (SO_3)	.86
Total	99.90

RATIONAL ANALYSIS.

Clay substance	1.79
Free silica	84.41
Impurities	10.05

Clay No. 108 requires 16 per cent of water for plasticity; has a shrinkage of 2 per cent, and has a tensile strength, raw, of 50 pounds.

A clay from a small valley is now being used at the Butler Brick Plant. The clay is prepared by the use of a disintegrator and granulator. It is tempered in a pug mill and molded in a soft-mud machine operated by steam power. The brick are burned in rectangular up-draft kilns of the clamp type. A sample of clay from the valley has the composition given below:

TABLE 103.

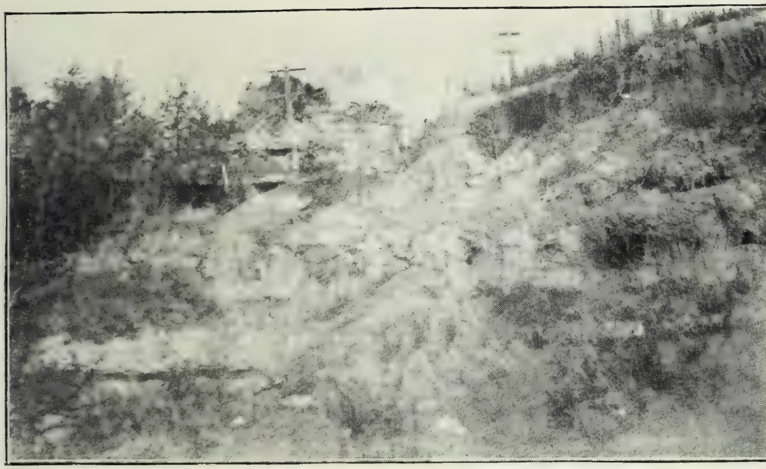
ANALYSIS OF BRICK CLAY, NEW ALBANY.

	No. 106
Moisture (H_2O)	1.10
Volatile matter (CO_2 etc.)	2.67
Silicon dioxide (SiO_2)	85.29
Iron oxide (Fe_2O_3)	3.44
Aluminum oxide (Al_2O_3)	4.44
Calcium oxide (CaO)	.44
Magnesium oxide (MgO)	.09
Sulphur trioxide (SO_3)	.17
Total	97.64

RATIONAL ANALYSIS.

Clay substance	11.23
Free silica	80.07
Impurities	4.14

Plate XL.



A. VICKSBURG LIMESTONE, VICKSBURG, DISTANT VIEW.

B. VICKSBURG LIMESTONE, VICKSBURG, NEAR VIEW.

The physical properties of clay No. 106 are: Water required for plasticity, 16 per cent; air shrinkage, 1 per cent; fire shrinkage, 1 per cent or less; tensile strength, raw, 65 pounds per square inch.

The Union County Brick and Tile Company has a plant a short distance south of the Butler yard. The clay in its pit has a thickness of 10 feet. The upper part is a brown loam clay, and the lower portion is red Lafayette. The top clay cannot be used alone in the manufacture of dry-pressed brick. The best results are obtained by using the bottom clay. A sample of the red clay has the composition given below:

TABLE 104.

ANALYSIS OF LAFAYETTE CLAY, NEW ALBANY.

	No. 107
Moisture (H_2O)	2.55
Volatile matter (CO_2 etc.)	4.05
Silicon dioxide (SiO_2)	77.99
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	8.37
Calcium oxide (CaO)	.06
Magnesium oxide (MgO)	.27
Sulphur trioxide (SO_3)	.51
Total	100.05

RATIONAL ANALYSIS.

Clay substance	21.17
Free silica	68.15
Impurities	7.09

Clay No. 107 has an absorption of 13.79 per cent; requires 18 per cent of water for plasticity; has a total shrinkage of 3½ per cent; has a tensile strength, raw, of 60 pounds per square inch, and burned of 50 pounds.

WARREN COUNTY.

GEOLOGY.

The bed rock formations of Warren County belong to the Vicksburg, Jackson and Grand Gulf stages of the Tertiary period. In the bluffs near the Mississippi and Yazoo Rivers in this county there are numerous exposures of Vicksburg limestone. Such outcrops are found both north and south of the city of Vicksburg. The road leading north from Vicksburg to the National Military Cemetery passes along the foot of the bluff, the lower portion of which is formed by an

almost unbroken wall of Vicksburg limestone. (See Plate XLVII.) The limestone consists of 5 to 6 layers, which are interbedded with marl. The limestone beds vary in thickness from 1 to 6 feet. A dark laminated clay or marl is exposed in a creek bed about 20 feet below these limestones. At a point where the cemetery road approaches the nearest point to Finnie Lake, the outcrop of limestone is capped with 30 feet or more of shell marl. The shells are very abundant. The upper portion of the marl contains lens-like clay stones which are brown on weathered surfaces and purple on fresh fractures. The surfaces of these stones are generally channelled and irregular. The marl contains some ironstone concretions of irregular shape. The freshly exposed marl is bluish gray in color. Under the action of the weathering agents it changes first to dark red or purple and finally to yellow.

The upper part of the bluff is capped by 20 feet or more of Loess. In other places it is thicker. Resting upon the Loess at Vicksburg there is a brownish colored clay which is used in the manufacture of brick. This clay is probably a residual product resulting from the decomposition of the Loess.

CLAY INDUSTRY.

Vicksburg.—The J. D. Tanner Brick Manufacturing plant was established about 1880. The brick are manufactured by the soft-mud process, being molded by hand. The clay is tempered in a ring pit. The brick are burned in rectangular up-draft kilns.

The clay pit, which is located on a hill, has the following stratigraphy, the divisions not being very clearly defined:

Section at Tanner Brick Plant, Vicksburg.	Feet
4. Soil	1
3. Loamy clay, grading into 2	2
2. More plastic clay	4
1. Loess	2+

No. 1 has a thickness of 50 feet or more in some places. It lacks plasticity and is not used by itself in the manufacture of brick. The remainder of the section seems to be the residual product, resulting from the weathering of the Loess. While retaining some of its physical characters, it has lost much of its soluble matter. Especially has the amount of calcareous matter been greatly reduced. The lime con-

EROSION IN BROWN LOAM AND LOESS, NATIONAL PARK, VICKSBURG.

cretions and the gastropod shells, so characteristic of the Loess, have disappeared. There is a decided gain in clay substances, consequently a gain in plasticity. The joint structure has been developed.

In the manufacture of soft-mud brick at the Tanner plant it is not possible to use the more plastic clay alone, so it is mixed with the Loess in the proportion of 1 foot of the latter to 5 feet of the former. Some of the physical properties of the clay are as follows: Its total shrinkage is only 3 per cent, practically all of which is air shrinkage. The raw clay has a tensile strength of 66 pounds per square inch. The burned brickettes have a tensile strength of 144 pounds per square inch. The addition of 23 per cent of water is necessary for plasticity. The loss of weight in passing from an air dried to a burned condition is 4 per cent. The burned brickettes absorb 12 per cent of water.

The Gregory Brick Manufacturing plant, established in 1906, is located in the southern part of Vicksburg. The clay used is taken from a pit on the side of a small depression near the plant. The clay changes from the surface downward from a sandy loam to a plastic joint clay. The Loess lies below the clay. It contains white lime concretions of irregular shapes, somewhat resembling potatoes with their protuberances. White gastropod shells are also abundant in the Loess. The clay is tempered in a ring pit and molded by hand. The brick are burned in rectangular up-draft kilns.

The Beck Brick Manufacturing plant is located on one of the Loess ridges in the southeastern part of Vicksburg. The plant was established in 1889. They use clay and loess in the proportion of 1 part of loess to 5 parts of clay. The treatment of the clay is similar to that of the other plants. It is tempered in the ring pit and molded by hand. After being dried in the open yard, the brick are burned in rectangular up-draft kilns.

The Garbish Brick Manufacturing Company operates a plant in the northern part of Vicksburg. The residual Loess clay is carted from the hill which rises above the low ground next to the river. The clay is mixed with the Loess in the proportion of 12 loads of clay to 3 loads of Loess.

The Thornton Press Brick Company operated a plant at Vicksburg until 1905, when the plant was burned. The residual Loess clay was used in the manufacture of dry-pressed brick.

WASHINGTON COUNTY.

GEOLOGY.

Washington County lies wholly within the Mississippi flood plain in the Yazoo delta. Its surface is occupied by the alluvium deposited during overflows from the river. The surficial material is of two types, viz., the sandy loams, so well represented on the borders of Deer Creek, and the dark "buckshot" clays, well developed in the Black Bayou region.

CLAY INDUSTRY.

Elizabeth.—A sample of clay collected from near the station at Elizabeth in Washington County has the following chemical composition:

TABLE 105.

ANALYSIS OF CLAY, ELIZABETH.	*No.* 58
Moisture (H_2O)	3.06
Volatile matter (CO_2 etc.)	3.94
Silicon dioxide (SiO_2)	69.22
Iron oxide (Fe_2O_3)	5.90
Aluminum oxide (Al_2O_3)	13.35
Calcium oxide (CaO)	2.75
Magnesium oxide (MgO)	1.15
Sulphur trioxide (SO_3)	.48
Total	99.85

RATIONAL ANALYSIS.	
Clay substance	33.77
Free silica	53.53
Impurities	10.28

The physical properties of the clay, so far as determined, are as follows: It has a total shrinkage of 5 per cent when burned to a hard state. It requires 19 per cent of water to render it plastic. The brickettes lose 10 per cent in weight in burning. They burn to a cherry red and are without cracks or checks. The tensile strength of the raw clay is 200 pounds per square inch. The burned brickettes have an absorption of 14 per cent. The clay is of fine grain and does not contain any gravel or large particles. A sandy type and a fat type are found within a short distance of each other, and are thus accessible for mixing. The railroad facilities at Elizabeth are excellent. This point is worthy of the investigation of those desiring to engage in the manufacture of brick and drain tile.

Greenville.—At Greenville the alluvial clay has been used in the manufacture of brick by the Greenville Dry Press Brick Company.

Plate XLII.

TYPICAL LOESS TOPOGRAPHY, VICKSBURG.

The clay is of a dark color and belongs to the "buckshot" type. The brick are molded in a dry-press machine and burned in up-draft clamp kilns. A sample of clay from this pit has the following chemical composition:

TABLE 106.

ANALYSIS OF ALLUVIAL CLAY, GREENVILLE.

	No. 49
Moisture (H_2O)	4.21
Volatile matter (CO_2 etc.)	11.78
Silicon dioxide	58.82
Iron oxide (Fe_2O_3)	11.30
Aluminum oxide (Al_2O_3)	9.70
Calcium oxide	1.40
Magnesium oxide (MgO)	2.01
Sulphur trioxide (SO_3)	.50
Total	98.72

RATIONAL ANALYSIS.

Clay substance	24.54
Free silica	47.42
Impurities	15.21

The burned brickettes have an absorption of 11.11 per cent. The clay slacks slowly. When stirred wet it forms hard clods. The clay requires 19 per cent of water to render it plastic. It has a total shrinkage of 10 per cent. In the raw state its brickettes have a tensile strength of 190 pounds per square inch When burned hard they are red in color and have a tensile strength of 632 pounds. In the process of granulation the clay may be reduced to spherical grains, which in the molding process are not entirely obliterated. Under such conditions the soft-burned brick may crumble. When the brick are hard-burned the grains are destroyed. Great care must be exercised in burning the clay at high temperature to avoid swelling and cracking.

Hampton.—A sample of alluvial clay collected from near the station at Hampton belongs to the sandy loam type and has the following physical properties: The total shrinkage is about 3 per cent. Its tensile strength, raw, is 53 pounds, and when burned it has a strength of 116 pounds. It requires 19.1 per cent of water to render it plastic. The clay loses 26 per cent of its weight in drying and burning, 7 per cent being lost between the air-dried and the burnt states. This sample was taken about 1 foot below the surface. Another sample taken from a lower level has a total shrinkage of 4

per cent. Its loss of weight in drying and burning is 24 per cent. Its absorption is 14.81 per cent. In the raw state it has a tensile strength of 180 pounds per square inch, and when soft-burned its strength is only 110 pounds. In grain it is coarse, but does not contain any loose particles.

WEBSTER COUNTY.

GEOLOGY.

Webster County lies wholly within the borders of the Wilcox (Lagrange) division of the Tertiary. The formation consists of clays and unconsolidated sands with intercalated beds of lignite. Many good pottery clays occur in the formation. A small hand pottery at Cumberland manufactures a general line of stoneware. One of the clays from this formation is used at Maben in the manufacture of white brick. The surface formations of the county consist of the sands and clays of the Lafayette and the loams of the Columbia.

The analysis of the white clay used at Maben in the manufacture of white brick may be seen on page 212.

WINSTON COUNTY.

GEOLOGY.

Winston County lies mainly within the Wilcox-Eocene, though there is a small area of Tallahatta buhrstone in the southwestern corner. The surficial deposits are of Lafayette and Columbia age. The Wilcox (Lagrange) contains some good beds of white pottery clays. It also contains beds of lignite. The chemical composition of one of the white pottery clays from the J. A. M. Loyd pottery pit near Webster is given below:

TABLE 107.

ANALYSIS OF POTTERY CLAY NEAR WEBSTER.

	No. 68*a*
Moisture (H_2O)	.47
Volatile matter (CO_2 etc.)	9.24
Silicon dioxide (SiO_2)	59.82
Aluminum oxide (Al_2O_3)	27.19
Iron oxide (Fe_2O_3)	1.26
Calcium oxide (CaO)	.49
Magnesium oxide (MgO)	.37
Sulphur trioxide (SO_3)	.31
Total	99.15

RATIONAL ANALYSIS.

Clay base	68.90
Free silica	18.11
Fluxing impurities	2.12

CLAY INDUSTRY.

Louisville.—The surface clays are used at Louisville in the manufacture of brick by two companies. The Storer and Miller Company have a yard located north of town on the line of the Mobile, Jackson and Kansas City Railroad. The clay used is a red clay, probably of Lafayette age. The upper portion is sandy. There seems to be about 6 feet of residual clay with a red and white clay below. The clay at this point is prepared in a disintegrator and granulator, and tempered in a pug mill. It is molded in an end-cut stiff-mud machine. The brick are dried in covered racks and burned in up-draft kilns.

Langley Brothers operate a brick plant south of Louisville. The clay used is a surface loam which is mixed with a white plastic clay underlying the loam. The general stratigraphy of the locality is revealed in a well near the pit.

Section of Well at Langley Brothers Brick Plant, Louisville.

	Feet
3. Surface loam (yellow)	6
2. Red and white clay and sand	15
1. Blue sandy clay with lignite	4

YALOBUSHA COUNTY.

GEOLOGY.

The Wilcox (Lagrange) formation forms the subsurface of Yalobusha County. The surficial deposits are Lafayette and Columbia. The brown loam of the latter is the principal clay used in the manufacture of brick in this county.

CLAY INDUSTRY.

Water Valley.—At Water Valley the clay of the surface formations is used in the manufacture of brick by the Norris Brick Manufacturing Company. The plant was established in 1904. The brick are molded in a stiff-mud machine of the plunger type. They are dried in open air sheds and burned in rectangular up-draft kilns. The brick

are sometimes dried in the sun without checking. The clay in the pit is of two kinds, a red clay at the bottom of the pit, probably Lafayette, and a brown clay overlying the red. The red clay cannot be used alone as it is too plastic. It may be used when mixed with the more non-plastic brown loam lying above.

YAZOO COUNTY.

GEOLOGY.

The chief bed rock formation of Yazoo County belongs to the Jackson division of the Eocene. It consists of clays, marls, sands and impure limestones, usually very fossiliferous. The bed rock is largely concealed by mantle rock belonging to the Pliocene, Pleistocene and Post-Pleistocene epochs. To the Pliocene may be assigned a series of cross-bedded sands, gravels and clays constituting the Lafayette formation. Both laterally and vertically the constituent materials of the formation vary greatly and pure beds of sand may be succeeded by pure beds of gravel and clay or by mixtures of the three. The colors are predominantly red, orange and yellow. The thickness of the formation rarely exceeds 50 feet. The Pleistocene is represented by the Loess and possibly by the Natchez formation, though the latter has not been definitely differentiated from the Lafayette in Yazoo County. The Loess is a very fine silt which in the process of weathering produces a surface loam with a clay substratum. The Columbia loam rests upon the Loess and, wherever the true Loess is absent, upon older formations. The flood plain of the Mississippi and the Yazoo Rivers in this county, called the Yazoo delta, is covered with alluvial material of Post-Pleistocene age.

There are two types of the alluvial material, a sandy loam and a plastic clay. The loam is generally light in color and of greater weight and is found near the streams. The clay is dark, light in weight and of finer grain and found in the interstream areas.

Topographically Yazoo County may be divided into the plain portion, that part included in the Yazoo Delta, and the hill portion, that section of the county lying east of the Yazoo River.

The surface of the county rises by means of an abrupt escarpment from the flood plain to the hill country. The flood plain area forms an exceeding level plain which lies about 100 feet above sea level.

The escarpment rises to a height of 250 to 300 feet above this plain. The surface descends from the escarpment toward the valley of Black River.

The river front of the escarpment presents a crenulated margin produced by small streams which have cut V-shaped valleys in its front. The position of the larger streams is marked by valleys with small flood plains which merge into the larger plain. The principal brick materials of the county are found in the residual clay of the Loess, and the clays of the delta, which may also be used for road ballast. Doubtless there are also deposits of the Lafayette and some residual clays of the Jackson which could be used in the manufacture of brick.

CLAY INDUSTRY.

Yazoo City.—A residual clay overlying the Loess at Yazoo City is used by the Montgomery Land Company in the manufacture of dry-pressed brick. The Loess assists in forming the bluffs along the border of the flood plain east of Yazoo City. These bluffs are mantled by residual clay, which is thin on the crest of the hills and becomes thicker in the depressions. On the steeper slopes it rarely ever reaches a thickness of 3 feet. In the depressions, however, a thickness of 8 feet is not uncommon. The clay substance usually increases toward the bottom of the pit. The Loess beneath is noticeably non-plastic as compared with the clay. The Jackson strata are revealed in outcrops near the base of the hills. The weathered surfaces of the exposures exhibit a gray joint-like clay containing shells. The clay is very plastic and seems to be free from sand. The Lafayette gravels rest upon the Jackson marls. The Lafayette covers the Jackson to the depth of 10 to 40 feet.

The chemical composition of the surface brick clay is given in the analysis below:

TABLE 108.

ANALYSIS OF SURFACE BRICK CLAY, YAZOO CITY.

	No. 60
Moisture (H_2O)	2.37
Volatile matter (CO_2 etc.)	4.37
Silicon dioxide (SiO_2)	72.65
Iron oxide (Fe_2O_3)	5.81
Aluminum oxide (Al_2O_3)	11.25
Calcium oxide (CaO)	1.12
Magnesium oxide (MgO)	1.62
Sulphur trioxide (SO_3)	.30
Total	99.49

RATIONAL ANALYSIS.

Clay substance	28.46
Free silica	59.42
Impurities	8.85

The above mentioned clay has a tensile strength of 85 pounds per square inch in the raw state, and 175 pounds per square inch in the soft-burned condition. Its total shrinkage is 4 per cent of which 3 per cent is air shrinkage. It requires 18 per cent of water to render it plastic. The soft-burned brickettes absorb 15.25 per cent of water.

TABLE 109.

DIRECTORY OF MISSISSIPPI CLAY WORKERS.

Name of Firm	Town	County	Product
1. Austin Brick Co	Pontotoc	Pontotoc	Brick
2. Bacon Brick Manufacturing Co	Greenwood	Leflore	"
3. Baldwyn Brick & Tile Co	Baldwyn	Lee	"
4. Bay St. Louis Brick Co	Bay St. Louis	Hancock	"
5. Beck Brick Co	Vicksburg	Warren	"
6. Bledsoe Brick & Tile Co	Grenada	Grenada	"
7. Bonita Brick Co	Meridian	Lauderdale	"
8. Booneville Brick & Tile Co	Booneville	Prentiss	Brick and tile
9. Brown Brick Co	Crenshaw	Panola	Brick
10. Brookhaven Pressed Brick Co	Brookhaven	Lincoln	"
11. Bushman & McGinnis	Hattiesburg	Perry	"
12. Butler Brick Co	New Albany	Union	"
13. Bullard Brick Co	Jackson	Hinds	"
14. Buchanan Brick Co	Sardis	Panola	"
15. Camp Brick Co	Amory	Monroe	"
16. Carl Brick Co	Grenada	Grenada	"
17. Cassiby Brick Co	Gulfport	Harrison	"
18. Centerville Brick Co	Centerville	Wilkinson	"
19. Charleston Improvement Co	Charleston	Tallahatchie	"
20. Clarksdale Brick & Tile Co	Clarksdale	Coahoma	Brick and tile
21. Clermont Brick & Tile Co	Biloxi	Harrison	Brick
22. Cline Brick Co	Macon	Noxubee	"
23. Columbus Brick Co	Columbus	Lowndes	"
24. Concord Brick Co	Natchez	Adams	"
25. Corinth Brick Co	Corinth	Alcorn	"
26. Cowgill Drain Tile Co	Minter City	Leflore	Drain tile
27. Edwards Brick Co	Edwards	Hinds	Brick
28. Erby Brick Co	Holly Springs	Marshall	"
29. Furtick Brick Co	Rienzi	Alcorn	"
30. Fernwood Lumber Co	Fernwood	Pike	"
31. Garbish Brick Co	Vicksburg	Warren	"
32. Graham Brick Co	Lumberton	Lamar	"
33. Greenville Brick Co	Greenville	Washington	"
34. Gregory Brick Co	Vicksburg	Warren	"
35. Gulo Brick Co	Holcomb	Grenada	"
36. Hancock Brick Co	Newton	Newton	"
37. Hawkins & Hodges	Okolona	Chickasaw	"
38. Hazlehurst Brick Co	Hazlehurst	Copiah	"
39. Howard Brick Co	Starkville	Oktibbeha	"
40. Imperial Brick Co	Biloxi	Harrison	"
41. Indianola Brick & Tile Co	Indianola	Sunflower	"
42. Jesty Brick & Lumber Co	Winona	Montgomery	"

TABLE 109—Continued.

DIRECTORY OF MISSISSIPPI CLAY WORKERS—CONTINUED.

Name of Firm	*Town*	*County*	*Product*
43. Landon Brick & Tile Co	Landon	Harrison	"
44. Langley Brick Co	Louisville	Winston	"
45. Laurel Brick & Tile Co	Laurel	Jones	"
46. Leakesville Brick Co	Leakesville	Greene	"
47. Love Wagon Co	Durant	Holmes	"
48. Lowery & Berry Brick Co	Blue Mountain	Tippah	"
49. Maben Brick Co	Maben	Oktibbeha	"
50. Magnolia Brick Co	Magnolia	Pike	"
51. Montgomery Brick Co	Senatobia	Tate	"
52. Montgomery Land Co	Yazoo	Yazoo	"
53. Mt. Olive Brick Co	Mt. Olive	Covington	"
54. Natchez Brick Co	Natchez	Adams	"
55. Nettleton Manufacturing Co	Nettleton	Lee	"
56. New Houlka Brick Co	New Houlka	Chickasaw	"
57. Norris Brick Manufacturing Co	Water Valley	Yalobusha	"
58. Ocean Springs Brick Co	Ocean Springs	Jackson	"
59. Oxford Brick & Tile Co	Oxford	Lafayette	"
60. Pope Brick Manufacturing Co	Houston	Chickasaw	"
61. Quitman Brick Co	Quitman	Clarke	"
62. Rheinhart Brick & Tile Co	Clarksdale	Coahoma	Brick and tile
63. Ripley Brick Manufacturing Co	Ripley	Tippah	Brick
64. Riverside Brick Co	Hattiesburg	Perry	"
65. Robinsonville Brick & Tile Co	Robinsonville	Tunica	Brick and tile
66. Saltillo Brick Manufacturing Co	Saltillo	Lee	Brick
67. Smith Brick Co	Canton	Madison	"
68. Storer & Miller Brick Co	Kosciusko	Attala	"
69. Storer & Miller Brick Co	Louisville	Winston	"
70. Success Brick & Tile Co	Greenwood	Leflore	"
71. Summit Brick Co	Summit	Pike	"
72. Sunflower Brick Co	Indianola	Sunflower	"
73. Tanner Brick Co	Vicksburg	Warren	"
74. Taylor & Thomas Brick Co	Crystal Springs	Copiah	"
75. Taylor Brick Co	Jackson	Hinds	'
76. Thrasher Brick Co	Thrasher	Prentiss	"
77. Thornton Brick Co	Vicksburg	Warren	"
77a Tubbs Brick Co	Amory	Monroe	"
78. Union County Brick & Tile Co	New Albany	Union	"
79. Utica Brick Manufacturing Co	Utica	Hinds	"
80. Vaiden Brick & Tile Co	Vaiden	Carroll	"
81. Valley Brick & Tile Co	Lake View	De Soto	"
82. Vardaman Brick Co	Vardaman	Calhoun	"
83. Verona Brick & Tile Co	Verona	Lee	"
84. Weems Brick Co	Sun	Scott	"
85. Welch-Trotter Brick Co	West Point	Clay	"
86. West Point Brick Co	West Point	Clay	"
87. White & May Brick Co	McComb City	Pike	"
88. Woodville Brick Co	Woodville	Wilkinson	"
89 Cumberland Pottery	Cumberland	Webster	Stoneware
90. Holly Springs Stoneware Co	Holly Springs	Marshall	"
91. Allison Pottery Co	Holly Springs	Marshall	"
92. Davidson Pottery	Miston	Itawamba	"
93. Kennedy Pottery	Miston	Itawamba	"
94. Stewart Pottery	Perkinsville	Winston	"
95. Loyd Pottery	Webster	Winston	"
96. Lockhart Pottery Co	Lockhart	Lauderdale	"
97. Moorhead Manufacturing Co	Moorhead	Sunflower	Drain tile
98. Summerford Pottery	Miston	Itawamba	Stoneware

ACKNOWLEDGMENTS.

The writer of this report desires to express his very great obligations to the men engaged in the manufacture of clay wares in Mississippi for the generous and cordial way in which they have responded to requests for information necessary to the completion of this report.

The chemical work included in this report was done under the direction of Dr. W. F. Hand, State Chemist, and to him and his corps of assistants all credit is due. A few chemical analyses derived from other sources are credited at their proper places.

The writer is indebted to Dr. Calvin S. Brown for some reports of brick plants and for the samples of lignites mentioned in the monograph. Also to A. F. Crider, Director of the Survey, for reports of brick plants, for reading the manuscript and for other courtesies extended.

In the preparation of the report the writer is under special obligations to the following reports and works on ceramics:

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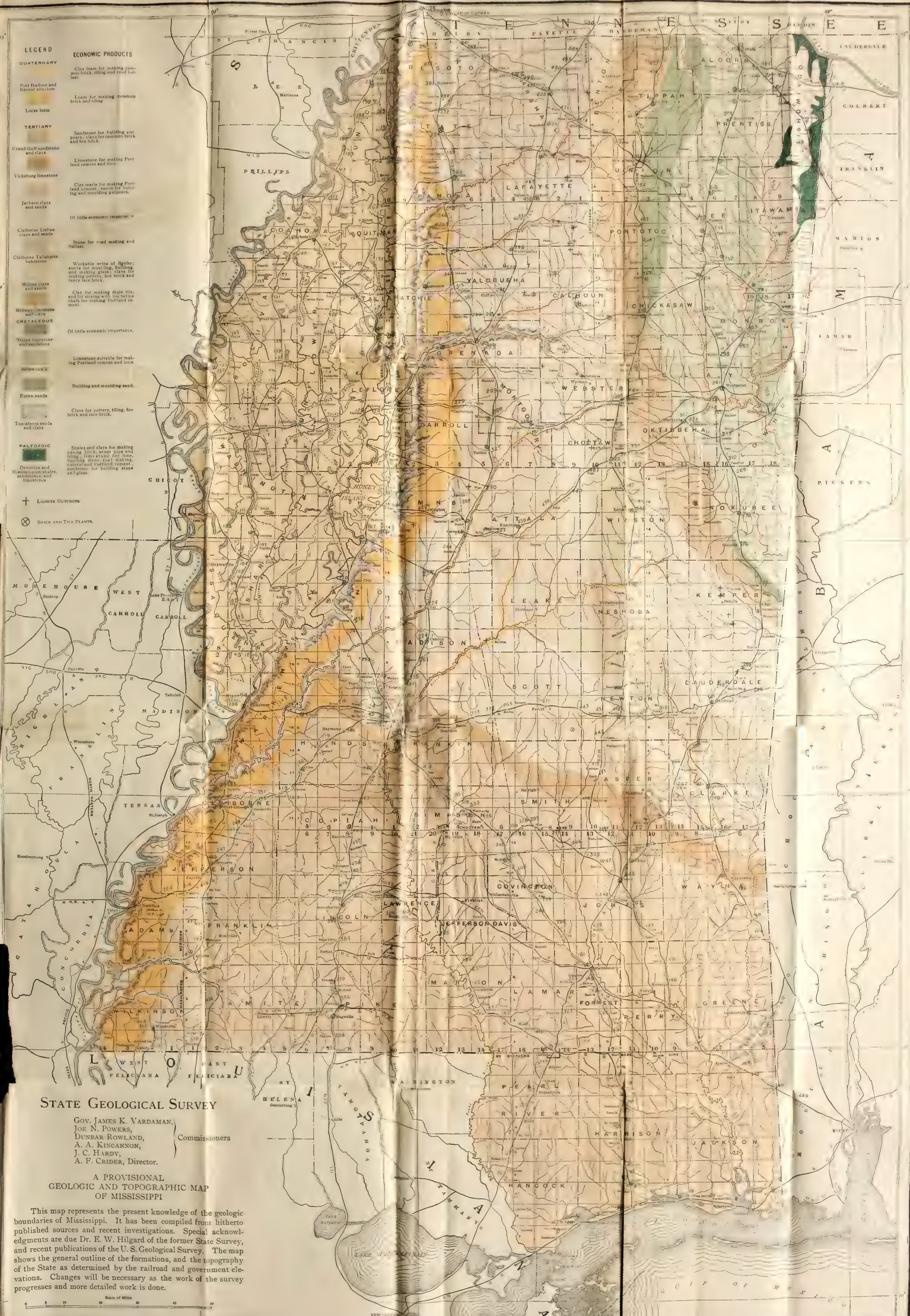
Pearson
Brandon
Star
Comsby
Butler
32°
30°



LEGEND
QUATERNARY
Port Hudson and Recent alluvium
Loess loam
TERTIARY
Grand Gulf sandstone and clays
Vicksburg limestone
Jackson clays and sands
Claiborne Lisbon clays and sands
Claiborne Tallahatta buhrstone
Wilcox clays and sands
Midway limestone and clays
CRETACEOUS
Ripley limestone and sandstone
Selma chalk
Eutaw sands
Tuscaloosa sands and clays
PALEOZOIC
Devonian and Mississippian shales, sandstones, and limestones
ECONOMIC PRODUCTS
Clay loam for making common brick, tiling and road ballast.
Loams for making common brick and tiling
Sandstone for building purposes, clays for common brick and fire brick.
Limestone for making Portland cement and lime.
Clay marls for making Portland cement, sands for building and moulding purposes.
Of little economic importance.
Stone for road making and ballast.
Workable veins of lignite; sands for moulding, building, and making glass; clays for making pottery, fire brick and fancy face brick.
Clay for making drain tile, and for mixing with the Selma chalk for making Portland cement.
Of little economic importance.
Limestone suitable for making Portland cement and lime.
Building and moulding sand.
Clays for pottery, tiling, fire brick and face brick.
Shales and clays for making paving brick, sewer pipe and tiling, limestone for lime, building stone, road making, natural and Portland cement, sandstone for building stone and glass.
LIGNITE OUTCROPS
BRICK AND TILE PLANTS.
STATE GEOLOGICAL SURVEY
GOV. JAMES K. VARDAMAN,
JOE N. POWERS,
DUNBAR ROWLAND,
A. A. KINCANNON,
J. C. HARDY,
Commissioners
A. F. CRIDER, Director.
A PROVISIONAL
GEOLOGIC AND TOPOGRAPHIC MAP
OF MISSISSIPPI
This map represents the present knowledge of the geologic boundaries of Mississippi. It has been compiled from hitherto published sources and recent investigations. Special acknowledgments are due Dr. E. W. Hilgard of the former State Survey, and recent publications of the U. S. Geological Survey. The map shows the general outline of the formations, and the topography of the State as determined by the railroad and government elevations. Changes will be necessary as the work of the survey progresses and more detailed work is done.
Scale of Miles
TENNESSEE
ALABAMA
LOUISIANA
GULF OF MEXICO

Mississippi State Geological Survey

ALBERT F. CRIDER, DIRECTOR.

BULLETIN No. 3

THE

LIGNITE OF MISSISSIPPI

By CALVIN S. BROWN

STATE GEOLOGICAL COMMISSION.

His Excellency, James K. Vardaman .... *Governor*

Dunbar Rowland .... *Director of Archives and History*

A. A. Kincannon .... *Chancellor of the State University*

J. C. Hardy .... *President Agricultural and Mechanical College*

Joe N. Powers .... *State Superintendent of Education*

GEOLOGICAL CORPS.

Albert F. Crider .... *Director*

William N. Logan .... *Assistant Geologist*

Calvin S. Brown .... *Assistant Geologist*

LETTER OF TRANSMITTAL.

JACKSON, MISSISSIPPI, July 20, 1907.

To His Excellency, Governor James K. Vardaman, Chairman, and Members of the Geological Commission:

GENTLEMEN—I submit herewith a report on the lignite of Mississippi by Dr. Calvin S. Brown, and respectfully recommend its publication.

Very respectfully,

ALBERT F. CRIDER,

Director.

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BIBLIOGRAPHY.

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LIGNITE IN GENERAL.

DEFINITIONS.

Lignite may be defined as immature coal or vegetable matter in the process of forming coal; it is a fuel intermediate in heating capacity between wood and coal. It belongs to a much more recent geological age than stone coal. Lignite is often mistaken for stone coal, especially when wet, but may be readily distinguished from it, even by the untrained observer, by noting the following differences. In general coal is black, whereas lignite is brown. When taken from water or when very moist, as many of the samples of Mississippi lignites are when first found, it appears rather black, but upon cutting with a knife exposes a brown surface; coal remains black when cut. When wet lignite is cut with a sharp knife it leaves a smooth surface or tends to do so, whereas coal when cut leaves a rough surface owing to its hardness and brittleness and tendency to fracture before the knife. Lignite upon drying cuts more like coal but is seldom as hard and compact. When a piece of dry lignite is put into water it gives out for some moments a characteristic crackling sound or click; this is not true of coal. The fracture of coal is bright and glossy, that of lignite usually dull. Lignite crumbles within a short time upon being exposed to the weather, whereas coal resists the influence of weathering much longer.

Reports of the discovery of coal in Mississippi are of frequent occurrence in the newspapers, and in most cases have their origin in the discovery of lignite. If the finder would take the trouble in the future to compare his material carefully with a piece of coal before spreading reports, many errors would be avoided. If after the first comparison there is still doubt in his mind, let him place the coal and the lignite side by side in the sun for a few days and the difference will become apparent. No true coal has ever been found in Mississippi, and judging from geological conditions there is little probability that it will ever be found.

There are within the lignite belts of Mississippi much lignitic clay and other lignitic earth. These contain more or less carbonaceous matter, but should not be confused with lignite. It is difficult of course to draw a hard and fast line between lignitic earth and earthy

lignite; still none of these earthy materials should be called lignite which have not enough carbonaceous matter to enable them to burn readily under average conditions. Lignite is sometimes called brown coal.

PHYSICAL PROPERTIES OF LIGNITE.

In color lignite is brown or in the best qualities black, shading at times toward yellow and red; the streak and powder are usually brown. Its luster varies from dull to brilliant according to the composition and the impurities in it. Its texture also varies within wide limits; in the purer, better qualities it is hard, firm, and compact; in others it is soft; in others brittle. Some specimens tend to crumble upon exposure much more readily than others. In some specimens the woody texture is obliterated; in others it is quite apparent; in some instances pieces of wood are found but slightly altered; in others pieces of logs completely silicified occur; and occasionally the same logs will be partly lignitized and partly petrified. Some samples of lignite show leaves, twigs, pine needles, and other small parts of plants. Lignite burns with both flame and smoke and gives off a disagreeable odor in the process. It does not fuse or cake upon burning, hence is not ordinarily available for making coke. Owing to the amount of earthy impurities the percentage of ash left after burning is frequently high. The specific gravity of lignite is usually less than that of bituminous coal and anthracite; sometimes, however, it is as high as that of bituminous coal, owing to earthy impurities contained. Roughly speaking we may put the specific gravity of lignite at 1.2 to 1.5. The fracture of lignite in some of the harder varieties is conchoidal, in other varieties it is irregular; in some the lignite tends to block in vertical lines, and it often has planes of cleavage parallel to the stratification; in the woody types there is cleavage parallel to the grain of the wood. Most lignites have the capacity of absorbing a large amount of moisture and when first mined the percentage may be as high as thirty-five or even fifty. When exposed to the air this moisture evaporates in part, as a result of which the lignite tends to disintegrate.

CHEMICAL PROPERTIES OF LIGNITE.

Coal and lignite are composed of carbon, hydrogen, oxygen, and nitrogen, the principal element being carbon. In addition to these

elements there are usually present as impurities sulphur and earthy matter. This earthy matter remains behind upon burning in the form of ashes. The following ultimate analyses of air-dried samples made by the St. Louis Coal-testing Plant of the United States Geological Survey in 1904 give an idea of the relative proportion of these constituents in bituminous coal and lignites:

TABLE I.

ULTIMATE ANALYSES OF COAL AND LIGNITE.

(By U. S. Geol. Survey.)

No.	Kind	Locality	C	H	O	N	S	Ash	Total	B.T.U.
1	Bituminous coal..	Bonanza, Ark....	80.03	4.13	3.20	1.40	1.90	9.34	100	13,961
2	Bituminous coal..	Kentucky........	78.31	5.36	8.80	1.85	1.24	4.44	100	14,319
3	Bituminous coal..	Carbon Hill, Ala..	69.24	4.79	10.87	1.55	1.02	12.53	100	12,449
4	Black lignite.....	Wyoming........	58.41	6.09	28.99	1.09	.63	4.79	100	10,355
5	Brown lignite....	Texas...........	57.31	5.28	25.83	1.06	.71	9.81	100	9,904
6	Brown lignite....	North Dakota....	55.16	5.61	30.98	.91	.63	6.71	100	9,491

It will be observed from the preceding table that in a general way the heating or calorific value (B. T. U., British thermal units) is proportional to the amount of carbon contained in the coal or lignite. It will be observed however that the Kentucky coal has a higher heating capacity than the Arkansas coal, although the latter has a slightly higher percentage of carbon; this is due to the large amount of ash or inert matter which the Arkansas coal contains. The oxygen in coal and lignite adds nothing to its value, as might be supposed at first thought, for the air furnishes all the oxygen needed for combustion; furthermore the part of the oxygen contained in the water (H_2O) is a positive disadvantage to the coal or lignite, as the water must absorb some of the heat in the process of vaporization.

Instead, however, of the method of ultimate analysis shown above, proximate analysis is usually employed for coal and lignite, as it shows the amount of fixed carbon and volatile matter (combustible constituents) and of water and ash (non-combustible constituents). It should be remembered, however, that not all volatile matter is combustible, especially in lignite. The following table of proximate analyses made on an air-dried basis will show the position of lignite as compared with other fuels:

TABLE 2.

COMPARATIVE ANALYSES OF COAL AND LIGNITE.

(From various sources.)

No.	Kind	Locality	Fixed Carbon	Volatile Matter	Water	Ash	Total	Sulphur	B. T. U.	Authority or analyst	Remarks
1	Anthracite...	Mammoth E. M., Pennsylvania	86.38	3.08	4.12	5.92	99.50†	.50	....	A. S. McCreath..	Average of 5 samples.
2	Anthracite...	Buck Mt., Pennsylvania.......	82.66	3.95	3.04	9.88	99.53†	.46	....	A. S. McCreath..	Average of 2 samples.
3	Bituminous...	Straight Creek, Kentucky.....	57.08	36.56	1.92	4.44	100	1.24	14,319	U. S. Geol. Sur...	Same as No. 2, Table 1.
4	Bituminous...	Murphreysboro, Illinois.......	56.03	34.62	4.96	4.39	100	.62	13,285	S. W. Parr......	Ill. G. S., Bull. 3.
5	Bituminous...	Carbon Hill, Alabama.........	51.74	33.15	2.58	12.53	100	1.02	12,449	U. S. Geol. Sur...	Same as No. 3, Table 1.
6	Bituminous...	Danville, Illinois.............	48.14	35.06	3.44	13.36	100	3.38	11,909	S. W. Parr......	Ill. G. S., Bull. 3.
7	Lignite.......	Choctaw Co., Mississippi......	42.47	34.61	11.61	11.31	100	2.66	10,071	W. F. Hand.....	E. W. Oswalt's land.
8	Lignite.......	Alba Mine, Texas............	41.71	42.01	6.15	9.35	99.22†	.78	....	E. T. Dumble....	Lignite of Texas.
9	Lignite.......	Texas......................	40.11	39.42	10.66	9.81	100	.71	9,904	U. S. Geol. Sur...	Same as No. 5, Table 1.
10	Lignite.......	Yalobusha Co., Mississippi.....	39.94	40.85	12.62	6.59	100	2.05	9,706	W. F. Hand.....	J. J. Milton's land.
11	Lignite.......	North Dakota................	39.49	37.10	16.70	6.71	100	.63	9,491	U. S. Geol. Sur...	Same as No. 6, Table 1.

†Sulphur to be added.

ORIGIN OF LIGNITE.

Lignite, like coal, is of vegetable origin. The process of formation of these fuels seems to be briefly as follows: vegetable matter accumulated to considerable thickness; this was then covered by water or earth, and ultimately by earth alone; chemical changes gradually took place by which oxygen was lost and the relative proportion of carbon increased; along with this, due to these chemical changes, to pressure, and perhaps to other causes, took place a considerable decrease in volume. The process of transformation was very slow and required vast geological ages for its completion. The various stages of this change may be seen in peat, lignite, bituminous coal, and anthracite, the transformation being least in peat and greatest in anthracite. In the lignites the vegetable structure is often still plainly visible, pine needles, small parts of plants, woody branches and trunks being frequently found. The woody matter occurs in all stages of transformation from simple wood to completely lignitized matter. Side by side in the same bed of lignite may occur a trunk of but slightly altered wood and a trunk of petrified (silicified) wood containing enough carbonaceous matter to make it brown or black. Indeed the same trunk is sometimes partly lignitized and partly silicified. The clay associated with lignite often contains well defined leaf and plant impressions.

GEOLOGICAL AGE OF LIGNITE.

It has already been said that lignite is of a later geological age than true coal. The true coals, that is anthracite and bituminous coal, belong principally to the Carboniferous Age (Paleozoic Era). Coal is also found in the Triassic and the Jurassic periods (Mesozoic Era). The black lignites or subbituminous coals of Colorado, New Mexico and Wyoming, and the brown lignites of North Dakota are found in the Cretaceous (late Mesozoic). The brown lignites of Texas belong to the Tertiary (Cenozoic Era). By far the greater part of the brown lignites of Mississippi, Alabama and Tennessee belong also to the Tertiary; some deposits, however, are found in the Cretaceous.

LIGNITE OF MISSISSIPPI.

FIELD WORK.

The field work for this report was begun on the 15th of June and finished on the 5th of September, 1906. During this time I visited all the localities in the State in which lignite had been reported to exist and brought to light many outcrops of which no written record existed. I examined in all about two hundred outcrops of lignite and took samples of fifty of the most promising of these. While I tried to visit every county and locality in which lignite was thought to exist, I found it impossible during the one summer at my command to inspect every individual outcrop of lignite reported to me in some of the districts where such outcrops are of frequent occurrence. In such cases I tried always to choose the best or most representative deposits for examination.

Very few of these deposits have ever been worked or opened with a view to commercial use. Many occur in or near the bottom of creeks and ravines and others in private springs. Hence in many instances it was found impossible to make as complete an examination as was desirable without the expenditure of more time and money than were at my disposal. It resulted in many cases that instead of taking samples throughout the vertical extent of the beds I was forced to take them from the top or the first ten or twelve inches of the bed, or from the most accessible point. Nor was I always able to measure the thickness of the strata, for the frequent presence of iron pyrite in the lignite made it impossible to use the extension auger in many instances.

THE LIGNITE AREA OF MISSISSIPPI.

The lignite area of Mississippi is that part of the State lying north of a line through Meridian, Jackson and Vicksburg, and east of the "Bluff." A few outcrops of lignite are found south of this limit, but they belong to later geological formations and are relatively infrequent and unimportant. The Bluff here mentioned is part of that line of bluff extending from Kentucky to Louisiana east of the Mississippi

River and parallel with it. Between Memphis and Vicksburg the river is deflected from the Bluff, leaving between the river and the bluff the low level country known as the "Delta." No lignite is found west of this line of Bluff in Mississippi.

The lignite area on the map published by the United States Geological Survey in the first volume of the Report on the Coal-testing Plant of St. Louis (P.P. No. 48) should be greatly extended—on the west to the line of the bluff, and on the north far into Tennessee.

Under the heads of Geological Formations, Distribution in Mississippi, and List of Localities, more detailed information will be given on the subject of the lignite area in Mississippi.

TOPOGRAPHY OF THE LIGNITE AREA.

The north-central area of the State, in which the lignite occurs, is characterized by a rough, hilly surface frequently cut by deep gullies. Along the larger streams the process of erosion has gone on until the valleys are several miles wide. A large part of the material on the surface or near the surface being sand, erosion is still going on rapidly in the hills and uplands. Much of the sand and earth thus washed down is redeposited along the streams and valleys. Consequently the surface of the country is changing constantly and rapidly. The elevation of the territory is nowhere great. The following railroad elevations, taken from Gannett's "Dictionary of Altitudes," will indicate the general range:

Railroad Elevations.

	Feet.
1. Lexington	209
2. West	290
3. Louisville	536
4. Ackerman	522
5. Coffeeville	241
6. Oxford	458
7. Holly Springs	602
8. Olive Branch	387
9. Hernando	391
10. Sardis	384

Holly Springs is the only railroad town in the State with an elevation above 600 feet. A point on the Illinois Central Railroad about 1½ miles south of Holly Springs (between mile posts 544 and 545) has

an elevation of 619 feet; this is the highest railroad point in the State. It is therefore doubtful if there are many hill-tops which exceed 700 feet. On the other hand the Delta lying west of the lignitic area and through which much of the latter is drained has an average elevation of about 150 feet; so that 200 feet may be taken as approximately the lower altitude limit of the lignitic area. Thus it is seen that the elevation of this territory ranges between 200 and 650 or 700 feet, a range which is not very great, and yet which is sufficient to give considerable inequality and diversity to the landscape. In fact, the character of the two upper geological strata are such that the resulting topography may in many places be called rugged.

THE GEOLOGICAL FORMATIONS OF MISSISSIPPI.

The nomenclature of the geological formations of Mississippi, as adopted by the present geological survey, is as follows:

TABLE 3.
THE GEOLOGICAL FORMATIONS OF MISSISSIPPI.

Cenozoic	Quarternary		River alluvium.	
			Yellow loam.	
			Loess.	
			Port Hudson.	
			Lafayette.	
	Tertiary	Miocene (?)	Grand Gulf.	
		Miocene	Pascagoula.	
		Oligocene	Vicksburg.	
		Eocene	Jackson.	
			Claiborne	Lisbon and undifferentiated Claiborne.
				Tallahatta buhrstone.
			Wilcox.	
			Midway	Porter's Creek.
				Clayton.
Mesozoic	Cretaceous		Ripley.	
			Selma Chalk.	
			Eutaw.	
			Tuscaloosa.	
Paleozoic	Carboniferous		Chester.	
			St. Louis.	
			Tullahoma.	
	Devonian		New Scotland.	

It will be seen from this table that the Archæan rocks are not represented in Mississippi, and by consulting the accompanying map it will appear that only a very small portion of the State belongs to

the Paleozoic age, the Devonian and Carboniferous being found only in a limited territory in the northeastern corner of the State. West of this is a broader strip extending north and south which is Mesozoic in time, the Cretaceous. About four-fifths of the State, however, belong to Cenozoic time, the Tertiary and Quarternary eras.

The great lignite-bearing series is that named by Dr. Hilgard the "Northern Lignitic," now known in the Government Survey and the State Survey of Mississippi as the Wilcox. This formation occurs in the Eocene period of the Tertiary.

Before describing in detail, however, the Wilcox formation, and other less important lignite-bearing series, it is necessary to say a few words about the general geological conditions in that part of Mississippi under discussion in this paper.

In the northern half of the State the strata dip westward or southwestward. On top of the older formations have been deposited in Quarternary times two much more recent formations, the Lafayette and the Columbia (or yellow loam). The following theoretical diagrams will help to make this matter clear:

Section of the Strata Exposed in the Lignite Area of Mississippi.

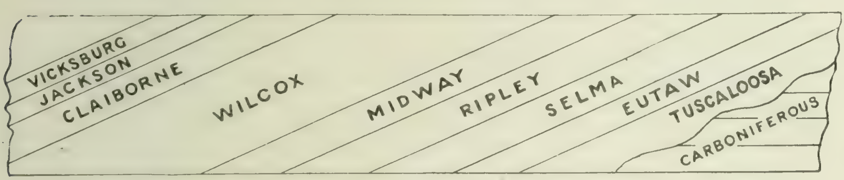

Fig. 1.

Fig. 2.

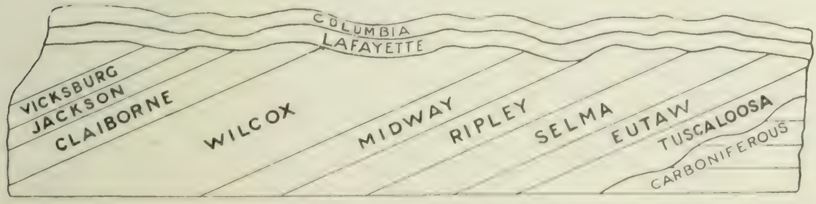

Fig. 3.

Figure 1 represents the older formations with an exaggerated dip toward the west and a surface unaffected by erosion. Figure 2 represents the same after the rains and streams have cut the surface into hills and valleys. Figure 3 represents the same at a still later period after the layer of sand and gravel known as Lafayette has been deposited unconformably upon the older formations following the surface of the hills and valleys and after a still later sheet of yellow or brown loam known as Columbia has been deposited upon the Lafayette.

The name Lafayette, from Lafayette County, Mississippi, was agreed upon in 1891 for the older name of Orange Sand used by Dr. Safford and Dr. Hilgard. But the name Orange Sand, and its equivalents, Lagrange and Lafayette, as used by Safford, Hilgard, McGee and Mabry, seems to include two entirely distinct formations, an upper thin bed of unstratified sand belonging to the Quaternary and a lower thicker formation consisting of stratified sand and other material belonging to the Tertiary. Mabry, in his paper on the Brown or Yellow Loam of North Mississippi, had, however, begun to "doubt the unity of the Lafayette." The present writer will use the term Lafayette to apply only to the upper generally unstratified member, considering the lower stratified sands and clays as Wilcox or other formations according to location. This will account for the discrepancy in thickness assigned to the Lafayette by the older writers and those of the present survey; Hilgard and Mabry speak of the thickness of the Orange Sand or Lafayette at Oxford, for example, as about 200 feet; I put it in the present paper at 2 to 8 feet, considering the stratified material below this as Wilcox. I have recently found strong evidence of the correctness of this view here in Lafayette County, the type locality of the Lafayette formation (as well as in many other places). Professor Mabry says: "Near Oxford, Miss., where the Lafayette is typically developed, it attains a maximum thickness of something like 200 feet. But towards the east it soon thins out, exposures of the Lignitic being quite common within 8 or 10 miles of Oxford." Now it happens that I have discovered a bed of lignite lying only 1 mile east of the courthouse at Oxford. The combined thickness of the material overlying the Wilcox at this point is not more than 20 or 25 feet.

The name Lafayette, then, as used in this paper, will apply only to that layer of sand, or sand and gravel, usually from 5 to 15 feet thick,

rarely exceeding 40 or 50 feet thick, which in Quaternary times has been deposited unconformably upon the older formations following the hills and slopes according to the conformation reached about the close of the Tertiary period. This sheet of sand, accompanied in some places by gravel, covers a large part of the State.

The Columbia formation is a deposit of from 3 to 15 or 20 feet of brown or yellow loam overlying in many places the sand and pebbles of the Lafayette and forming the topmost and most recent deposit in upland regions. It is usually unstratified, non-calcareous, and non-fossiliferous.

Here should be mentioned also, because of its association with the lignitic area, the Bluff loess. This is a fine gray or buff-colored calcareous deposit occurring above the Lafayette and containing calcareous concretions and snail shells and other land and fresh-water fossils. It is a narrow belt from 6 to 15 or 20 miles wide extending along the Bluff the whole length of the State, and in its typical form is easily recognized by the characteristics just given and its tendency to stand in vertical walls along roads and gullies. Whether the Bluff loess is a separate and distinct formation as held by Hilgard, or merely a peculiar manifestation of the Columbia (yellow loam) as maintained by some later writers, will not be discussed in this report. For convenience, the name Columbia will be limited in this paper to the brown or yellow loam and the name Loess or Bluff Loess used for the narrow belt or calcareous snail-bearing silt along the Bluff.

THE WILCOX.

The Wilcox is the great lignite-bearing formation in Mississippi. It belongs to the Eocene period of the Tertiary era. This formation was called by Hilgard the Northern Lignitic, and was included by Safford of Tennessee in his LaGrange or Orange Sand group and his Bluff Lignite. The name Lagrange is continued by L. C. Glenn in his recent paper on the "Underground Waters of Tennessee and Kentucky West of Tennessee River."*

The Wilcox or Lagrange is the broadest in extent and the thickest in depth of all the formations within the territory under discussion in this report, excepting always, of course, so far as extent is concerned the two surface formations, the Columbia and the Lafayette. Suffic-

*U. S. Geol. Survey, W. S. and I. Paper No. 164, 1906.

ient data for the determination of the exact thickness do not as yet exist, but it is certain that it is at least several hundred feet thick, not improbably reaching at places the depth of 600 to 1,000 feet.

The materials of this formation consist principally of stratified clays, sands and lignite or lignitic earth. The clays are usually white, whitish, cream, pink, chocolate, or light blue in color, and at a distance often give the appearance of chalk or sand banks. Frequently the clays are stained brown or black with lignitic or carbonaceous matter. Many of these clays are quite pure, others are very sandy in nature. Often they contain well defined Tertiary leaf impressions. In large masses the fracture is frequently conchoidal. The sands are usually stratified and varied in color, red, yellow and orange being the prevailing types. The lignite will be mentioned at greater length under its proper head.

The character of the better Wilcox clays may be judged from the following analyses made by Dr. W. F. Hand, and recorded in Logan's "Clays of Mississippi," 1905, and Crider's "Geology and Mineral Resources of Mississippi," 1906.

TABLE 4.

ANALYSES OF WILCOX CLAYS.

(By Dr. W. F. Hand.)

Constituents	*No.* 1	*No.* 2	*No.* 3
Silica (SiO_2)	67.70	57.79	59.82
Alumina (Al_2O_3)	19.69	26.03	27.19
Ferric oxide (Fe_2O_3)	3.04	2.98	1.26
Lime (CaO)	1.06	.44	.49
Magnesia (MgO)	.58	.10	.37
Sulphur trioxide (SO_3)	.19	.24	.31
Moisture (H_2O)	.94	1.14	1.47
Loss on ignition	6.64	9.11	9.24
Total	99.84	97.83	100.15

No. 1 is the Holly Springs Stoneware Company's clay; No. 2 is from Oxford near the negro schoolhouse; No. 3 is the Cumberland Stoneware clay of Webster County.

Typical exposures of the Wilcox (or Lagrange) may be seen at Holly Springs, Oxford, Pittsboro, Bellefontaine, Chester, Louisville, Dekalb and Lockhart.

Like the other formations within the area discussed in this report, the Wilcox is generally overlain by the Lafayette and the Columbia. The following sections give an idea of the surface appearance within the Wilcox area, it being understood that in no case is the whole of the Wilcox exposed.

Section at Oxford near the Railroad Bridge.

	Feet
Columbia, loam	8–12
Lafayette, unstratified orange sand	2–5
Wilcox, strat. white and cream sand and clay	28

A short distance south of the bridge the Columbia rests almost directly upon the Wilcox. At other places in Oxford the Lafayette is better developed than at the railroad bridge.

Section from Hill Just West of Grenada. (Crider, p. 28.)

		Feet
Yellow loam and Lafayette (capping hill)		x
Wilcox	Impure laminated gray clay	50
	Green sands with thin layers of clay	50
	Darker colored laminated clays	50

Section in I. C. R. R. Cut 1½ Miles East of Ackerman.
(Taken on north side at deepest part.)

		Feet
Columbia		9
Lafayette sand		16
Wilcox	Stratified clay and laminated shale	18
	Lignitic shale and clay	⅛
	Stratified clay, etc	10

OTHER LIGNITE-BEARING FORMATIONS.

Besides the Wilcox formation other geological formations in Mississippi contain lignite to some extent. Among the older formations the Tuscaloosa in the northeastern part of the State contains a number of beds, for instance those in Itawamba County. Among the formations more recent than the Wilcox (or Lagrange) the Claiborne and the Grand Gulf are known to contain carbonaceous deposits, and such deposits are at least associated with the Jackson and Vicksburg formations if not actually contained in them. The lignite beds of Holmes County, now assigned to the Claiborne, are among the best in the State; here the beds are numerous and attain a thickness as great as any in Mississippi.

THE GEOLOGICAL MAP.

A geological map accompanies this report. The Wilcox, the great lignite-bearing formation, is shown by the broad area with light brown hachures. The Claiborne formations, the Lisbon and the Tallahatta buhrstone, are shown respectively by the area with darker brown hachures and that with brown dots. The Tuscaloosa in the northeastern corner of the State, also a lignite-bearing formation, is represented by the field with green dots. The location of lignite beds is shown on this map by blue crosses. No attempt has been made to indicate the extent of the individual beds.

MODE OF OCCURRENCE OF LIGNITE.

As there are generally two surface formations, the Columbia and the Lafayette, overlying the lignite-bearing formation, it rarely happens that lignite appears at the surface on level ground. This can occur only where the two upper formations have been eroded and the lignite occupies the topmost member of the Wilcox or other lignite-bearing formation. More generally lignite is exposed in gullies or ravines and in the beds of streams. It is, therefore, to be sought at the foot of hills or near their bases and in cuts and ravines rather than on the hill-tops. Springs often form a good index to its outcrop, for both lignite and the clays associated with it are impervious to water; hence the surface waters which find their way readily through the Lafayette sand are deflected when they strike the lignite or the associated clay and flow along these strata till they find an outlet at some lower level. Lignite is frequently struck in digging or boring wells.

The materials most closely associated with lignite are usually the various types of sands and clays. Sands are generally found at no great distance above the lignite, for even if there is present no stratified sand of the same age as the lignite, it will not be very far up to the unstratified Lafayette sand. Immediately above the lignite, however, is frequently found a few feet of clay. No stone or slate roofing of consequence is found over the lignite beds of Mississippi. It sometimes happens, however, that the last inch or two of a sand layer resting directly upon a deposit of lignite is converted into ferruginous sandstone by a cement of iron oxide from a flow of iron-impregnated water arrested in its downward course by the bed of lignite.

Immediately below the lignite is usually found clay, sometimes of excellent quality. Not infrequently the underlying clay is deeply colored with lignitic matter. The associated sands are also sometimes carbonaceous in character.

The following partial sections will help to make clear the character of the materials immediately associated with the lignite beds of Mississippi:

Section at Chester Near the Jail. (Sample 7.)

Sandy clay	x
Lignite	21 inches.
Poor lignite or lignitic clay	9 inches.
Clay	x

Section 1½ Miles North of Dekalb. (Sample 15.)

Sand	x
Sandstone	2 inches.
Lignite	27 inches.
Lignitic clay	x

Section at Shenoah Hill Near Tchula. (Sample 23.)

Sand	x
Tough clay	2 feet.
Lignite	4–5 feet.

Section Near Shawnee, Benton Co. (Sample 29.)

Sand	15 feet.
White to bluish clay	5 feet.
Lignite	2½ feet.

Section at Shelby Creek Church, Benton Co. (Sample 32.)

Sand	8 feet.
Yellow clay	6 inches.
Claystone	4 inches.
Yellow clay	3 feet.
Lignite	1 foot.

Section at Old Wyatte, Lafayette Co. (Sample 37.)

Unstratified sand	32 feet.
Stratified sand	8 feet.
Woody lignite	scarcely 1 foot.
Stratified sand	24 feet.

Section at Camp Springs Near Pittsboro. (Sample 43.)

Good lignite	28 inches.
Fossiliferous clay	7 feet.
Inferior lignite	6 inches.

THICKNESS OF BEDS.

Dr. Wilder, in a report on the lignite of North Dakota (p. 12), 1905, mentions one bed in that State with a thickness of 40 feet, and adds, "three beds that reach a thickness of 25 feet are known, while beds 15 feet thick are not uncommon." Unfortunately no such thicknesses as these can be reported for Mississippi. Beds beyond 3 feet in thickness are not very common and those beyond 5 feet are very unusual. The thickest strata which the present writer has been able to find are the following:

Thickest Lignite Beds in Mississippi.

(1) "Burning bed," near Lexington, Holmes Co. (Sample No. 21), thickness 7⅓ to 8 feet.
(2) Shenoah Hill, Holmes Co., thickness 5 to 6 feet.
(3) Coal Bluff, on Pearl River (Sample No. 18), thickness somewhat over 5 feet.

It should be said that the thickness of some of the lignite beds has not been determined, and that other beds of greater thickness than these have been reported.

Casual observers are often deceived in the thickness of the deposits owing to the fact that the associated clay, shale and sand are frequently highly lignitic in character and dark in color, and hence are readily mistaken for lignite. At Coal Bluff on Pearl River, for instance, the best lignite is only 17 inches thick, and the total thickness only 4½ to 5½ feet, yet, owing to the associated material, a person rowing along the river gets the impression of a solid bed of 8 feet or more. It is, therefore, frequently necessary to take reported thicknesses with a grain of allowance. The 14, 16 and 20-foot beds of lignite mentioned by Harper (pp. 168, 199) I have not been able to find.

The thicknesses mentioned in this report are usually maximum thicknesses, unless something to the contrary is indicated.

UNCERTAINTY OF BEDS.

The persistence of the beds, both as to thickness and as to lateral extent, is by no means certain among the Mississippi lignites. Beds change in thickness with remarkable rapidity, often thinning out or even disappearing within a few yards. A good outcrop on one side

of a hill may not reappear at all on the opposite side of the hill a quarter of a mile away, or may not be found even across the valley or ravine twenty yards distant. That uniformity and continuity of stratum so desirable for mining are frequently wanting. In the railroad cut near Topton, Lauderdale County, for instance, a stratum of poor lignite or lignitic shale between 3 and 4 feet thick practically disappears in both directions at a distance of 50 yards. In the "burning bed" in Holmes County the lignite seems to thin out in every direction from a point where it is about 8 feet thick. It would seem that in general the lignite has been deposited in lenticular masses and that the diameter of the lens is often small.

Those seeking to develop lignite beds should not base their calculations on one limited outcrop, but before investing much money should determine the lateral extent of the deposit and the thickness at various places. This may usually be done by boring, and in some cases by digging with hand tools. In boring with small augers care should be taken not to mistake the pulverized borings of shale or lignitic clay for those of lignite; else the lignite will appear to be thicker than it really is, and the whole calculation will be vitiated. Having determined roughly the area of the lignite bed and the thickness of the deposit at several places an approximate estimate can be made of the quantity of the fuel present.

VARIATION IN QUALITY.

The quality of the lignite differs greatly in different deposits, running through all the gradations from lignitic shale and clay to a compact, pure, dark brown lignite. In some places it is difficult to determine whether we should call the material lignitic clay or mucky lignite, lignitic shale or shaly lignite. In some beds the deposit is moist and soft, in others dry and firm. In some beds the plant remains are abundant and wood may be found but slightly altered, in others the material is completely lignitized. In some beds much iron pyrite or other impurity is found, in others very little. The chemical composition, as will be seen further on, varies greatly in different beds. Not only do the beds differ one from another in quality, but there will often be found great difference in quality within the same bed. The upper part of a stratum may be soft and mucky, while the lower part is hard and compact. The upper part may be

comparatively pure and good, while the lower part may contain much clay or earth. Part of a bed may be completely lignitized while another part of it is but imperfectly converted; even the same trunk may be partly lignitized and partly petrified. The bed at Coal Bluff on Pearl River shows this variation in quality; at one place the partial section is as follows:

Section of Coal Bluff, Pearl River.

Lignitic shale	3¼ feet.
Solid lignite	17 inches.
Laminated lignite	3 feet.

This variation within the same bed is shown further by chemical analyses; different samples often showing quite different results.

SOME COMMON ERRORS.

Several popular errors exist in connection with the occurrence of lignite One of these is that "the lignite gets better further under the hill." There is no reason for this supposition if we disregard a few inches of weathered lignite on the exposed surface. Another statement often heard is that "the lignite probably gets thicker further under the hill." It has already been stated that the lignite deposits are usually lens-shaped; a little reflection will therefore make it plain that the beds may get thicker or may get thinner, and that it is just as likely to be the latter as the former; it all depends on where the lens-shaped mass happens to be first pierced or eroded away. A third error is that "under the lignite one will find real coal if he goes deeper." This supposition is likewise without foundation either in practice or in theory. In not a single instance in Mississippi has coal ever been found under the lignite. In fact, the presence of the lignite points to the absence of stone coal, for lignite is of a much more recent geological time than true coal; hence if true coal existed at the same place as lignite it would probably be so far below the surface that its discovery would be improbable and its utilization impracticable. The true explanation of all three of these popular misconceptions lies in Shakespeare's principle, "the wish is father to the thought."

This may be an appropriate occasion to notice a question frequently put to me in the field: "How long will it take lignite to become good coal?" The discussion of this question may be of interest to the

scientist, but it does not concern the land-owner or practical miner from a commercial point of view. The rate of transformation is so slow that neither our children nor their children's children will note any appreciable change. From a practical point of view, then, the lignite must be considered as lignite and not as a prospective future coal.

BURNING BEDS.

Beds of lignite undoubtedly catch fire and burn for long periods of time. Reports of such beds have frequently been current in Mississippi; for instance, the bed on Mr. Black's land near Pleasant Hill, De Soto County; the railroad cut near Lockhart, Lauderdale County; the bed on Mr. Barron's land in Choctaw County, and several strata in Holmes County. The writer of this report found only one bed actually on fire during his investigation in the summer of 1906, the bed 6 miles southwest of Lexington, Holmes County, which will be described further on in this report. Wilder, writing of North Dakota (p. 52), says: "Evidence is at hand at nearly every point within the lignite area which shows that great quantities of this valuable fuel have been destroyed by fire. Thick masses of burned clay, red, brown, white, or vitrified to a dark glassy slag, cap many of the low buttes, or lie in confused heaps on the slopes. From Fryburg to Medora the Northern Pacific Railway passes through a region in which 'scoria,' as the burned clay is called, is particularly abundant. It makes an admirable railroad ballast."

LIST OF LOCALITIES BY COUNTIES.

DE SOTO COUNTY.

At Pleasant Hill, 5 or 6 miles south of the Tennessee line, there is a deposit of lignite at the church spring, the thickness of which I did not determine. In a well not far away it is reported to be 4 feet thick. In the ravine south of the church-yard are large pieces of thin sheets of lignite, the source of which could not be traced. Two miles west of Pleasant Hill, on Mr. P. M. Black's land, there is a bank in which lignite is said to have burnt for several months. This bank is grown up and covered over now, so that considerable digging failed to discover the bed of lignite; a number of pieces of lignitic clay and a few pieces of clayey lignite were thrown up however. On the creek on the Williamson place ½ mile north of this bank is an outcrop of 2 feet (probably not all exposed) of poor lignite.

MARSHALL COUNTY.

The present writer found no good lignite in his brief trip across the southern part of Marshall County, although he heard reports of lignite in wells. On the Malone place, 1 mile east of Lawshill, there is a deposit of 5½ feet of very poor lignite, better called lignitic sand and earth, with abundant particles of mica and some iron pyrites. A. F. Crider (p. 62) reports a thin band of lignite in the Allison Stoneware clay pit east of Holly Springs. Harper (p. 242) says lignite is found "in Marshall County, especially in the southern part, on the Tallahatchie River."

BENTON COUNTY.

On Mr. W. E. Hoover's land, Sec. 2 (?), T. 4, R. 1 W., not far from Shawnee, there is a bed of lignite in the bottom of Royston's Creek. The section is as follows:

Section on W. E. Hoover's Land, Near Shawnee.	Feet
Sand	15
White to bluish clay	5
Lignite	2½

This lignite blocks out well, and seems good. Some of it contains plant impressions. I noticed no iron pyrites. The sample (No. 29)

did not reach the laboratory. Wailes (P. 239) mentions a deposit not far from here on Snow Creek, Sec. 7, T. 4, R. 1 W., 7 miles south of Salem.

Two miles east of Floyd lignite outcrops in Mr. John C. Orman's house spring. I could not determine the thickness without disturbing the spring, but about 14 inches are exposed. The lignite blocks out well, but with some tendency to flake. It has some sand in it, but I saw no pyrites in the small amount examined. The analysis shows this lignite to be unusually high in volatile matter, but relatively low in fixed carbon. Above the lignite is a thin sheet of sandstone. Water flows out just above the lignite. (Sample No. 30.)

On Mr. J. D. Rutledge's land, Sec. 33, T. 3, R. 2 E., at an old spring in the horse-lot, is a stratum of lignite now covered by sand. I examined only the top of the deposit, which seemed firm but contained too much sand and iron pyrites. (Sample No. 31.) The analysis shows 48 per cent of ash, which would indicate that if all the bed is like the top it has no fuel value.

At Shelby Creek Church (Geddy's Chapel), on the old Tolbert place, about ¾ of a mile from the preceding and near the Tippah County line, there is an outcrop about two-thirds of the way down the ravine. Thickness 1 foot. This flakes rather than blocks out, and has a great many strips of earthy matter in it. (Sample No. 32.) Analysis yields over 63 per cent of ash or inert matter, which shows the lignite to be worthless for fuel purposes.

Lignite is reported deeper down in the gulch. Lignite is also reported at various other places in the county, which I had not the time to visit. Some of these are as follows:

Five miles north of Ashland on Mr. H. R. Littleton's place, 1 mile from Wolf River, 4 feet thick. At Glenn mill, 5 miles east of Ashland, probably 2½ feet thick, good quality. One mile south of Pinegrove, on Mr. Rennick's place; was used by a blacksmith when mixed with charcoal. On Mr. West's place, 2 miles northwest of Pinegrove.

TIPPAH COUNTY.

There are no doubt lignites in Tippah County, although I did not find them, owing to lack of time and to incompetent guides. They are reported about the headwaters of Tippah. Hilgard (p. 160) reports it on 'Squire Street's land, Sec. 29, T. 3, R. 33 E., in a ravine

between two steep hillsides, although he apparently did not see it, as he speaks of having no opportunity of observing the quality. Lignite is also reported on Shelby Creek, 2 miles south of Finger, and on the Hensley place near the latter.

TATE COUNTY.

At Sarah on the Coldwater River there is an outcrop of lignite in the railroad cut. The stratum here is not very thick and the fuel weathers and crumbles to pieces. One hundred yards further from the station in the ravine east of the railroad is a good exposure of lignite, the thickness of which was not determined. Mr. Brown, the owner of the land, says that this was once exposed 12 feet and that there was still lignite below. On the hill above he says they bored into lignite respectively 7 feet, 5 feet and 8 feet, without passing through the bed. Some of this lignite seems fair in quality, except that it contains iron pyrites and earthy matter. (Sample No. 27.) Chemical analysis shows too little fixed carbon and too much ash, resulting in a heating capacity of only 8,022 B. T. U. Lignite is also reported on Mrs. Johnson's place, near Sarah.

PANOLA COUNTY.

Panola County contains a lignite center in the vicinity of Tocowa. In a ravine a short distance behind the hotel at Tocowa, Sec. 8, T. 10, R. 8 W., is a bed of solid lignite 16 inches thick. In color it is brown with a slight tendency to red on the outside. (Specimen No. 25.) This contains very little sulphur but leaves nearly 20 per cent of ash.

Down the valley, ¾ of a mile or 1 mile further, there is a stratum of excellent lignite in the bed of a small bluff stream, thickness probably 17 to 19 inches, color dark brown, approaching black. (Sample No. 2.) This is superior to the stratum near the hotel, containing less than one-third of the amount of ash and much more combustible matter. It has 9,930 heat units per pound as compared with 8,471 in the hotel sample. Other beds are reported in the vicinity of Tocowa Springs.

At Nirvana, 2 miles east of Tocowa, Sec. 10, T. 10, R. 8 W., there is in Mr. S. E. Anderson's field a bed of firm solid lignite in the bottom

of a wash. A thickness of only 12 inches is exposed, but the sand has covered the bottom and I did not learn the full thickness.

On the Sam Darby place in the same section, about 1 mile from Nirvana, there is a stratum of lignite in the bed of a ditch immediately below the gravel. This lignite seems firm and good, resembling that at Tocowa and Nirvana. The sample, No. 26, never reached the laboratory. Near here the remains of an opening said to have been made for lignite about 1869 are still visible. It is said that the lignite found in this bed would burn.

It was somewhere near Tocowa that Harper (p. 199) reported a bed of lignite "at least 16 feet thick, and perhaps much thicker . . . an inexhaustible quantity of it." I could get no trace or rumor of such a deposit.

LAFAYETTE COUNTY.

Lafayette is one of the richest counties in lignite in the State. There are two lignitic belts trending east and west, the northern along the Tallahatchie River, the southern and more important along the Yocona River.

Under the site of the old town of Wyatte on the north bank of the Tallahatchie, a town once important but of which not a single house now remains, runs a thin stratum of poor lignite and imperfectly converted vegetable matter. This bed scarcely reaches 1 foot in thickness. (Sample No. 37.) Analysis shows over 39 per cent of ash.

Further up the river, about 3 miles above the Illinois Central Railroad bridge, there is an outcrop of lignite 18 inches thick on Mr. Tidwell's land in the south bank of the river just above water level. This lignite blocks out in large lumps but has much sand in it; when dry it is variegated with bands of earthy matter. There is a stratum of sandstone 2 inches thick above this bed and the slope of the ground back from the river is gentle. (Sample No. 34.) The analysis shows 45 per cent of ash, too much for the lignite to be of any value.

About ⅜ of a mile south of the last mentioned bed near Mr. E. A. Billingsley's shop on the Tidwell land, 3½ miles east of Abbeville, there is a bed of lignite which abounds in streaks of sand and in iron pyrites. I could not get through it with the auger because of the latter. Sand can be shaken from dry specimens of this lignite in

great quantities. The top is very impure; deeper down the quality seemed better. The analysis of a sample from near the top shows over 49 per cent of ash.

About 1 mile west of Caswell postoffice, on Mr. Jesse Barry's land, in the bed of a stream right on the Abbeville and Pontotoc road, is a stratum of lignite remarkable in the number of forms it assumes. In some places it is merely lignitic earth, then there are all varieties up to firm good lignite. In some places the woody structure is retained. One piece of wood occurring under good lignite is scarcely altered from its original condition. Another log is partly lignitized and partly petrified. This stratum extends up the nearly dry bed of the stream a distance of 100 yards or more; the ground is level on one side and the hill is very gentle on the other. Thickness 21 inches where bored. (Specimen No. 35.) The analysis of a sample including several different types from this bed shows an inferior lignite. Analysis from selected samples would no doubt show better results.

It is thus seen that the lignites of the northern belt of Lafayette County are not very promising, at least so far as examined. Among the better beds in the southern lignitic belt may be mentioned the following:

On Mr. W. J. Hogan's land, Sec. 32, T. 9, R. 2 W., nearly 2 miles southwest of Oliver's bridge, there is an outcrop of lignite in the bed of a stream (usually dry). Some of it is rather earthy, and some of the remainder is incompletely lignitized and shows woody structure, pine needles, plant impressions, etc. The bed may be called 2 feet thick, although the lower part passes into lignitic clay in such a way that it is hard to draw the line between the two. The analysis shows very little sulphur. It is easily accessible. (Sample No. 47.)

On Mr. A. D. N. Lancaster's land, near Delay, Sec. 33, T. 9, R. 2 W., there is an exposure of good lignite about 28 inches thick, in a narrow ravine part of the way down a steep hill. The analysis shows 9,398 thermal units per pound. (Sample No. 48.)

Lignite is also reported further west or down the Yocona than the two beds just described. Mr. W. J. Thweatt, for instance, reports 20 inches of lignite on his place about 5 miles west of Delay. The specimen brought to me at the University contained too much earthy matter to burn.

One mile east of Tula on Mr. W. W. Grimes' land, Sec. 7, T. 10, R. 1 W., in his fine spring near the house, there is a bed of firm lignite apparently good which he says he knows to be at least 1½ feet thick. It contains some earthy impurity and some pyrites.

A little further east on his farm in the bed of Sandy Creek there is a stratum of hard firm lignite in which there seemed to be very little impurity, although I have not examined a dry sample of it. The auger went about 30 inches before striking the clay; apparently 18 inches of this was firm and solid and 12 inches of a softer nature with perhaps more earthy matter. This bed is quite accessible and would be very convenient for local use in Tula.

Lignite is also found in Mr. Jack Coleman's spring, ½ mile south of Tula. I took out a small piece, which seemed of excellent quality, but could do no more without disturbing the spring.

On Mr. R. V. Edward's land, in a tributary of the Potlockney, Sec. 26, T. 10, R. 2 W., 1 mile north of the county line, is an extensive exposure of lignite, the most extensive I have seen in the State. It forms the bed of the creek for a long distance, sometimes being 10 to 15 feet wide and rising at places 3½ feet above the bed of the stream while still forming its floor. It is of varied quality, much of it is solid and good; some of it retains its woody structure; but I saw none of the wood silicified. Some of the lignite contains sand and other impurities, and, according to Mr. Edwards and his son, iron pyrites. At some places where there seems to be much clay the lignite has a conchoidal fracture. This bed lies near the public road and is easily accessible. (Sample No. 50.) A dry sample of this gave a good welding heat in the University forge. When taken fresh from the bed it contains from 25 to 51 per cent of moisture. Mr. Edwards says he strikes lignite in all his wells.

On Mr. M. A. Garner's land, Sec. 30, T. 10, R. 1 W., about 1 mile north of the county line, in the bank of Patison Creek, is heavily lignitic shale and clay more than 4 feet thick. Near by a hole has been dug from which much better samples are said to have been taken, and the pieces which I saw bore out this testimony; unfortunately my examination was incomplete owing to the fact that the hole is now largely filled. There are reports of very good lignite from this place, even sufficiently good for welding. Dr. Hilgard (pp. 160, 161) mentions still other places in the southern part of the county where lig-

nite is found. A 6-foot seam is reported in a well at Paris (Crider, p. 88.)

A mile east of Oxford, in a gully in front of a house occupied by a negro named Allen Burt, there is a 6-inch bed of poor lignite, the greater part of it more properly called lignitic earth perhaps.

PONTOTOC COUNTY.

My drive southeast from Oxford extended no further than the Pontotoc County line, as I could learn from no one in the vicinity of outcrops in the adjacent parts of Pontotoc County. Hilgard says (p. 160): "Lignite beds probably occur in R. I, E., TT. 9 and 10, S. W. Pontotoc, as they do in the adjoining portions of Lafayette, but I have no *definite* knowledge of outcrops anywhere in Pontotoc County." Mr. Crider (p. 88) also mentions lignite in southwestern Pontotoc County, but whether the lignite at the two places noted on his field map occurs in outcrop or in wells he does not now (June, 1907) remember.

ITAWAMBA COUNTY.

Lignite is reported at a number of places in Itawamba County, not all of which could be examined by the present writer.

Four and three-fourths miles southeast of Fulton, 75 yards to the east of the Tilden road, there is a bed of lignitic matter on Mr. Huston's land, Sec. 18, T. 10, R. 9 E., with a thickness of 20 to 21 inches. This is soft on top, almost lignitic clay, but harder toward the middle, and contains iron pyrites. It is smooth and glossy, showing plainly the clay which it contains. This bed thins out to nothing 20 feet to the south and apparently does so to the north at a short distance. (Sample No. 3.) The chemist reports that the sample contains 25 per cent of ash, over 3 per cent of sulphur, and that it failed to burn.

On Mr. E. A. Palmer's land, Sec. 9, T. 10, R. 9 E., I examined two beds, one about 13 inches thick, the other near the church about 12 inches thick. (Samples No. 4 and No. 5). Both beds contain too much sulphur, as is evident to the eye. Chemical analysis shows No. 4 to be a worthless sample, with 61 per cent of ash, and No. 5 to be a sample of only medium quality. Mr. Palmer reports a third bed on this piece of land, which I did not have time to examine.

On Mr. Wm. Reed's land, Sec. 17, T. 10, R. 9 E., there is an opening into the hill which he made for lignite, but sand has fallen into it and it contains water, so I was unwilling to enter it. Mr. Reed gives the thickness as about 30 inches. Sand lies above the bed.

Lignite is also reported to exist south of Tilden and north or northeast of Fulton in this county.

MONROE COUNTY.

Mr. Dean reports that he struck lignite in two wells about 1½ miles from Greenwood Springs; the first he abandoned after going into the lignite about 6 inches, in the second he passed through 3 feet of lignite. He reports troublesome gas in the wells. By digging in the old well-heap I found pieces of the lignite, which showed distinct woody structure.

Lignite is reported to exist at several places southeast of the Greenwood Springs station across the Buttahatchie River, but my brief visit led me to believe that the quantity is small.

CALHOUN COUNTY.

The Calhoun County lignites are among the very best in the State. Several beds are reported in the extreme northern part of the county, Sections 11 and 12, T. 11, R. 2 W., only one of which I examined, and that superficially. Mr. Crider (p. 88) reports that the outcrop on Mr. J. A. Head's land, near the one I examined, is 5 feet thick. A sample of this lignite was exhibited at the Exposition in St. Louis. Mr. Head informs me that there are two outcrops on his land.

At Reynold's gin and mill, near Trusty Postoffice, there is a 7-inch stratum of lignite in the stream. At Parker's (?) spring, 1 mile from Trusty, there is a 17-inch seam with plant impressions, iron pyrites and sand. At Rock Branch school-house, 2 miles from Ellard, I found a small quantity of highly laminated lignite in a recent well-heap.

Pittsboro, in the central part of the county, and Slate Springs, in the Southern part, are centers of good lignite containing very little sulphur.

Sample No. 42 is from a well-heap in Pittsboro just east of the city square. This lignite is said to lie 15 feet below the surface and

to be 4 feet thick. In color it is black or almost black. It leaves only 7½ per cent ash and contains but little sulphur. Lignite crops out again in the spring 200 or 300 yards north of the square as a poor shaly material and is reported to be struck in many wells. Harper says (p. 214): "The inhabitants meet the lignite stratum everywhere, about 30 feet below the surface, and find it to be in some places of the unusual thickness of 30 feet; the latter is especially the case eastwards of the town, in which direction the stratum of lignite seems to increase in thickness."

At Camp Spring, ½ mile northwest of Pittsboro, the water runs over about 28 inches of good lignite. (Sample No. 43.) One log of wood in this bed is comparatively little altered. This lignite stands the wear of water well. It contains, according to analysis, a very high percentage of volatile matter. About 7 feet of clay underlies this stratum and below the clay is a 6-inch stratum of inferior lignite.

Both 42 and 43 could be used for heating and power in Pittsboro. For instance, an electric plant could be located at Camp Spring for lighting the town and would have both water and fuel convenient. Water could also be pumped into town from this spring. Of course a more thorough investigation should first be made as to the total amount of lignite present and the proper machinery for lignite consumption should be employed.

Another outcrop is found in a spring on Mr. B. F. Harrelson's land, not far away; thickness of stratum undetermined, and no sample taken.

The lignites of the southern part of the county show a still higher calorific value than those of the vicinity of Pittsboro. On Mr. John McPhail's land, 2 miles from Slate Springs, a shaft was sunk for lignite, which has now fallen in, so that I could not see the fuel in place. I took my sample, No. 44, partly from the exposed heap and partly from the coal-house, each part being 18 months old. The lignite is said to lie about 18 feet below the surface and to be about 8 feet thick and of uniform quality. It crumbles upon exposure, as most lignites do. Its color is black, or almost a solid black. As the analysis shows, this is an excellent lignite.

In the house spring on the Tom Walton place, 1 mile west of Slate Spring, there is an outcrop of 1 foot of good solid lignite which blocks out well. The analysis shows this (Sample No. 45) to have

next to the highest number of heat units of any specimen examined. The lignite occurs just below sand and has a high hill above it.

The Calhoun County lignites when dry will burn well in an open grate. The writer tried a scuttle of this fuel, composed of a mixture of samples 42, 43, 44, 45, in his own grate and obtained a steady, good fire, which burned up completely.

There are reports of lignite in the vicinity of Burke, both in wells and in outcrop, one outcrop being in the bank of Schouna River. Hilgard (p. 161) mentions lignite in the vicinity of Sarepta, and in township 12, range 2 west, and also on the river just below Old Town.

YALOBUSHA COUNTY.

Yalobusha County contains considerable lignite. In the extreme eastern part of the county there are two beds, one 19 inches thick on Mr. B. French's land 1 mile west of Airmount, the other 15 inches thick on Wash Hamblett's land not far away. Both of these lignites are firm and solid, but seemed from a field examination to contain considerable earthy impurity, and the latter much iron pyrites. They are capped by a thin shell of sandstone and lie under high hills. Lignite is struck in many wells about Airmount, according to the reports of the citizens.

Six and a half miles east of Coffeeville, on J. J. Milton's land, Sec. 5, T. 24, R. 7 E., there is a bed of excellent lignite outcropping in a big spring. This lignite is firm, compact and uniform in character so far as examined; the thickness is from 22 to 29 inches. Two inches of sandstone roof the bed, the hill above is gentle, and the location accessible. Sample No. 46.

There are reports of lignite at Vann's old mill race 3 miles south of Yalobusha across the Schouna River, and at or near Pine Valley. Wailes (p. 239) reports lignite at McElroy's mill on Turkey Creek.

TALLAHATCHIE COUNTY.

On Mr. B. M. Baker's place, 4 or 5 miles north of Charleston, Sec. 3, T. 25, R. 2 E., there is a bed of very poor lignite. I could not take the depth with the auger on account of the iron pyrite, which exists here in greater quantities and larger pieces than I have seen elsewhere in lignite. The sample, No. 24, shows over 6 per cent of sulphur after the lumps of pyrites were removed.

Three miles north of Charleston is a deposit of lignite which was opened some years ago but is now covered over. The fragments in the heap were badly weathered and flaked into thin layers, and contained leaf impressions. Mr. Craig is of the opinion that this bed was about 3 feet thick, and that is was tried in the shops with only moderate success.

A bed is reported to have been exposed in the creek north of Mr. Sherman's, but to be now covered with sand. Thin layers are reported also southeast of Payne's.

WEBSTER COUNTY.

Lignite is found in the central and northwest parts of Webster County. At Bellefontaine there is a bed of good lignite, measuring 19 inches thick where it crops out in the road. (Sample No. 40.) This contains very little sulphur and at the place where the sample was taken is quite dry. The University blacksmith tried a fire of this lignite under my direction and found it to give a good welding heat. It gave off numerous sparks in burning. This bed is very convenient for local use in Bellefontaine.

At the base of the same hill, in a gully, is a thinner and poorer stratum of lignite.

Lignite is reported to exist 1 mile southeast of Bellefontaine; at McCain, 2 miles northwest of Bellfontaine; on Mr. A. P. Magnes' place, 2 miles northeast of Bellfontaine, and at a place 1¾ miles northwest of Embry. Mr. L. L. Hammond says that he always strikes lignite in his borings about Dabney.

At the old Carver place, 3 miles northeast of Alva, there is an exposure of lignite in the stream not far from the bridge. The thickness could not be determined. This lignite is inferior to the Bellefontaine sample, having more extraneous matter. Sample No. 39 was taken from the upper part and was water worn.

Farther north, near the northwest corner of the county, on the Mr. W. M. Jenkins' place, there is said to be considerable lignite from 7 to 16 feet below the surface, and from 4 to 5 feet thick. There is no outcrop, but I saw a small quantity of small fragments at the house, and it seemed to indicate a good quality. This is said to burn in the forge.

CHOCTAW COUNTY.

Choctaw County is relatively rich in lignites. The six samples collected from this county all show over 9,000 B. T. U. and four of them show over 9,400. The sample from Mr. Oswalt's is the only one found in the State with over 10,000 B. T. U. The Choctaw County lignites contain more sulphur than the Calhoun County samples, but somewhat less moisture.

Sample No. 6 is from Mr. W. A. Collins' land in the southeastern corner of the township, 6 miles from Ackerman. The bed is 29 inches thick, the upper part of it showing a decidedly woody structure.

Sample No. 7 is a good lignite from the town of Chester, occurring at the spring just below the jail. It contains rather too much sulphur but is very convenient for local use. The thickness is 20 to 22 inches, with 9 inches of poorer lignite or lignitic clay below. There are at least three other exposures in Chester.

Sample No. 8 is from the old Moses Bridges place, now belonging to Mr. J. R. Ray's mother, Sec. 33, T. 18, R. 10 E., presumably the place mentioned by Hilgard (p. 162). The bed of the creek has been turned aside and the lignite is now covered. A sample was taken from a heap thrown out two years ago. The thickness was not determined; Hilgard gives it as about 4 feet (if the beds are identical), which is more than Mr. Ray remembers it to have been when he opened it two or three years ago. Some of the lignite was lighted with a small wood fire by the side of the road; it ignited with difficulty, but was still burning two hours later.

Sample No. 9 is from Mr. Patrick Ray's land, Sec. 32, T. 18, R. 10 E., about 1 mile from the preceding. This bed is probably 12 to 15 inches thick and is underlain by an equal thickness of lignitic shale.

Sample No. 10 is from Mr. E. W. Oswalt's place, Sec. 2, T. 17, R. 11 E. There are four outcrops of lignite on this farm, two of which I saw. The sample is from the second, which I examined, the first being in a spring. In color it is from brown to black. The analysis shows for this the highest heating capacity of all the lignites examined, the result of a very high percentage of fixed carbon. The bed is 32 inches thick, the lower 10 inches not being so good. Beneath is a blue clay. This lignite when tried in the University forge came rapidly to a sharpening heat and soon gave a good weld.

Mr. Oswalt thinks the two other outcrops in the next hollow of about the same character. On Mrs. Dora Oswalt's place, about ½ mile away, is another outcrop of similar character, Mr. Oswalt reports.

Sample No. 11 is from a spring in Mr. P. M. Snow's field, Sec. 15, T. 17, R. 11 E. This bed was visited late in the afternoon, when I did not have time to reach the bottom of it; hence the thickness cannot be given. This is an excellent lignite with a small amount of ash and a large amount of volatile matter.

At Mr. Snow's house in Section 14 of the same tract, the well-borers report striking lignite 4 feet thick at a depth of 24 or 25 feet. This thickness may include lignitic shale or clay. One hundred yards away in the railroad cut lignite of a poor quality crops out.

A 2-foot bed of lignite on Mr. W. Y. Barron's land, 6 miles north-east of Ackerman, is reported to have caught fire in the summer or fall of 1905 and to have burnt for 2 months, causing a disagreeable odor for 1 mile or farther.

On the old Henry Wood place, at the spring, 1½ miles north of Chester, Sec. 35, T. 18, R. 10 E., there is an outcrop of about 3 feet of hard, laminated lignitic shale or clay, scarcely to be called lignite. It contains pyrites and plant impressions. (See Hilgard, page 162.)

Another outcrop is reported 3 miles from Chester and 1½ miles from the Woods place, where shaly lignite outcrops; this is said to be sufficiently good for sharpening but not for welding. Lignite is also reported on the Busby place 10 miles north of Ackerman and 3 miles west of Reform. I failed to find it in the brief time at my disposal.

Hilgard (p. 162) records that a stratum of lignite 4 feet thick was struck in a well at a depth of about 45 feet at Black's well, Sec. 23, T. 17, R. 10 E., and (p. 161) that dark lignitic clay with a vein of lignite crops out on a bluff ½ mile southwest of Bankston.

WINSTON COUNTY.

"North Winston abounds in lignite. It is found in a stratum 4 feet in thickness, in wells near New Prospect Postoffice and east of the same on the headwaters of Noxubee, where it crops out abundantly in gullies and is struck in wells north of Webster. I have had no opportunity of observing these beds personally." (Hilgard, p. 162.) In a hurried drive from Louisville to Webster and vicinity I

found no lignite, but only lignitic clay, beyond Drip Spring, although there are still reports of such beds. A more careful search might reveal them.

Louisville, the county seat of Winston County, is in a lignitic area. Reports indicate lignite in a number of places. The well-borers, who were sinking a well at the livery stable at the time of my visit, reported striking lignite at a depth of about 40 feet.

On Mr. W. E. Huntley's land, 2½ miles west of Louisville, Sec. 31, T. 15, R. 12 E., is a bed of 1 foot of fair lignite. (Sample No. 12.) It has nearly 3 per cent of sulphur and rather too much ash, but a relatively small amount of water. Mr. Huntley says he did all his blacksmith's work, including welding, for two or three years with this lignite. He reports two other outcrops in the southeast corner of the same section.

The box of Drip Spring, 2½ miles north of Louisville, is cut in lignite of good quality. The thickness is probably about 2 feet. The analysis shows this to be higher in fixed carbon than any other Mississippi lignite analyzed, and it is the best of the Winston County lignites examined. (Sample No. 13.) If it should prove to be present in sufficient quantities it could be used for heat and power in Louisville. No doubt it could be used to advantage in the forge.

On Mr. C. L. Taylor's land, 3 miles northwest of town, there is a bed of good lignite, whose thickness is undetermined, but which is at least 41 inches. (Sample No. 14.) This contains but little sulphur. Dried samples show light splotches of earthy matter.

Eleven and one-fourth miles east of Louisville, near Perkinsville, is a very thin, insignificant sheet of lignite on Mr. J. W. Chapel's land. There are reports of lignite in other parts of the county.

NESHOBA COUNTY.

No outcrops of lignite were found by the present writer in Neshoba county, but the well-diggers and others report lignite as occurring in wells in and about Philadelphia. Wailes (P. 239) mentions a deposit on Sec. 30, T. 11, R. 12 E., near Philadelphia.

KEMPER COUNTY.

Two samples of good lignite were obtained from Kemper County. No. 15 is from Mr. H. A. Hopper's land 1½ miles north of DeKalb.

A horizontal opening has been made into the side of the hill following this stratum some distance and the lignite is shown to be fairly uniform. Measurement showed the thickness to be 27 inches, which Mr. S. O. Bell, chancery clerk at DeKalb, thinks increases further back. This lignite contains too much sand and earthy matter, otherwise it is good. Mr. Bell says it has been used in the forge for welding. A 2-inch sandstone cap covers the bed, above which is sand; below the lignite is black lignitic clay. Mr. Bell reports that lignite crops out in several places in this same hollow; I saw one other, where the stratum seemed about 1 foot thick.

There is another outcrop on Mr. Hopper's land about a mile north of town in a spring near a tenant house. This seemed of good quality from a field examination; thickness unascertained.

On Mr. L. J. Wimberley's land 4½ miles north of DeKalb is an outcrop of lignite of about 29 inches in thickness. The quality did not appear so good as Mr. Hopper's. There is no roof of stone about it. Mr. Wimberley reports another outcrop about a mile north of this, which he thinks is probably better.

At Pool's mill 4 miles southeast of DeKalb, Sec. 14, T. 10, R. 16 E., there is a 2-foot outcrop of good firm lignite which blocks out in large lumps. It seemed to be of uniform quality so far as exposed, and contains some iron pyrites. Mr. Pool says he cannot use it to advantage in his shop. That is perhaps because he did not dry it sufficiently. The percentage of sulphur is also rather high. The quantity of ash is unusually small for Mississippi lignites and the percentage of fixed carbon unusually high; hence its heating power is greater than that of the Hooper lignite north of DeKalb.

Mr. Pool reports another outcrop ½ mile away on his place, of about the same quality, but a little thinner. Lignite is also reported near Cullum and Spinks in the southern part of the county.

LAUDERDALE COUNTY.

At Lockhart, in a spring behind Mr. E. P. Brown's store, there is an outcrop of 11 inches of lignite apparently good except the top inch or two, which is soft and mucky. Below is lignitic clay, above is yellow sand. Mr. Brown says there are other outcrops and that it also occurs in wells about Lockhart.

There is considerable lignitic clay between Lockhart and the deep cut on the Mobile and Ohio Railroad 2 miles above town. This cut is reported to have been on fire for some time, but there is now no trace of present or past burning. There is much lignitic earth, but very little true lignite here.

In the railroad cut ¼ mile north of Topton there is a stratum of lignitic shale which can perhaps be called lignite, especially at the bottom. At the thickest it is between 3 and 4 feet. It seems to be lenticular in shape and practically disappears at fifty yards right and left. Within this stratum petrified logs appear completely surrounded by lignitic matter. These are brown to black in color. Within 5 feet of the largest of these logs is another log slightly enough changed from its original condition to be easily whittled with a knife. Below the lignitic stratum is a compact stratified green (or bluish) slightly micaceous sand, which splits off and lies in the stream like great stones. The cut just beyond, at the 145 mile-post, is said to have burnt for many years, the fire being hidden but the smoke showing above the ground.

Hilgard (pp. 118, 162) reports lignite in the wells at and about Marion and on Sowashee Creek, 2½ miles north of Marion. Mr. J. R. Hobgood, who lives about 4 miles north of Marion Station, says he struck two or three feet of lignite in digging his well ten years ago, and that his brother who lives near him found it in a well more recently dug.

In Russell I was informed that lignite of various thickness is struck in digging wells and that it outcrops in the creek near by with a thickness of 1 foot.

In the deep cut on the railroad east of Russell just before reaching the 287 mile-post there are two strata of about 1 foot each of heavily charged lignitic earth or lignite.

About 2 miles east of Russell on the railroad there are several abandoned shafts and galleries formerly used by the Meridian Fertilizer Co. In the cut between two of these workings there is exposed a 3½ foot stratum of poor lignite, with plant remains and much clay —no doubt the same stratum as the one used by the fertilizer company. The use of this lignite as an ingredient in the Meridian fertilizer has been abandoned for some years. Twenty or twenty-five

feet above this stratum in the same cut is another stratum about 1 foot thick, which being difficult of access was not examined.

Hilgard (p. 162) mentions the report of "black mud" found in Daleville; this may mean lignite, but more probably lignitic earth.

JASPER COUNTY.

Near Garlandville, Jasper County, on Suanlovey Creek, there is a bed of lignite, showing upon analysis a high percentage of volatile matter. I visited the vicinity but it was not convenient to examine the deposit, so the sample (No. 17) was sent to me later by Dr. Loughridge. This bed was visited in the early days by Dr. Hilgard, who reported it (pp. 127, 163) as occurring between the Claiborne and Jackson group and being exposed to the thickness of 2 feet above the bed of the stream with a probable continuation below; he speaks of the quality as good.

RANKIN COUNTY.

A stratum of lignite less than one foot thick occurs in the cut just east of Rankin. Mr. J. A. Spears of Rankin informs me that a test well at the tank struck 3 feet of lignite at a depth of 30–33 feet. The well at the mill struck two thin sheets of lignite and a thicker one. In Mr. S. R. William's well 3 miles east of Rankin 18 inches of solid lignite is reported.

Dr. Hilgard (pp. 108, 140) reports lignite at and north of Brandon, but the quantity seems small. I could get no trace of any beds of importance there. Harper (p. 168) reports it "in Rankin County, where it crops out in a cut on the railroad."

HINDS COUNTY.

Hilgard and others have reported lignites in the vicinity of Jackson, but these reports are so unpromising as to have led me to consider it unnecessary to make further investigation. Dr. Hilgard (pp. 130, 131, 163) reports 1 foot of earthy lignite at Moody's Branch near Jackson. He also reports (p. 163) finding "chunks of good lignite at a sandy bluff on Pearl River, about 1 mile (by land) above Jackson," without being able to ascertain the dimensions of the bed in place.

Wailes says (p. 239): "Mr. Fairchilds informs me that in sinking a well on Sec. 11, T. 4, R. 3 W., he encountered a bed of considerable thickness, 35 feet below the surface." Harper mentions lignite in the same township and section as "about 20 feet thick, and perhaps connected with the Vicksburg deposit."

Mr. Crider (p. 36) reports a 6-inch bed of lignite in a deep branch in the southern part of Sec. 15, T. 4, R. 1 E., not far from Byram. This, he thinks probable, marks the break between the Vicksburg and the Jackson formations.

CLAIBORNE COUNTY.

In Claiborne County there is lignite occurring within the Grand Gulf formation. In T. 13, R. 3 E., about 2½ miles southwest of Mr. Bagnell's, is a deposit between the sandstone strata of the Grand Gulf. This lignite is about 1 foot thick, closely laminated, weathers into flakes and contains many lumps of iron pyrites. Apparently it contains much impurity and would leave a high percentage of ash. Another outcrop is reported about 3½ miles southwest of Hinkinson on Foster and Dochterman's land, and is said to be about 1 foot thick.

Wailes (p. 239) mentions a 2-foot exposure of lignite near Big Black River occurring between two strata of the Grand Gulf sandstone, but there is some error in the text as to the geographical location, as it is placed in Sec. 47 [sic], T. 13, R. 2 E. Harper (p. 168) reports lignite on Big Black River, T. 13, R. 3 E.

WARREN COUNTY.

On account of the high stage of the river at the time of my visit I was unable to examine the lignite stratum reported at Vicksburg. Wailes (pp. 237, 238) says:

"The most considerable deposit of lignite, by far, which has come under my observation, is that at Vicksburg. This I had a favorable opportunity of examining on the 10th of October, 1852, owing to an unusually low stage of water in the Mississippi, it being rarely exposed to view. On that occasion I measured 500 yards on its surface, along the margin of the river, and obtained specimens of it. . . . The thickness of the bed I had no means of ascertaining, no excavation having been made."

Dr. Hilgard (pp. 141, 164), on the authority of Prof. Moore, speaks of this as solid, lustrous lignite not exceeding 3 feet in thickness.

YAZOO COUNTY.

At Mr. Joe Dilley's house half way between Phoenix and Mechanicsburg I found one small outcrop of lignite 2 to 3 inches thick in the bottom of a stream. Another small outcrop is reported further down the creek, equally insignificant.

Harper (p. 168) says: "Another remarkable stratum of very fine lignite is found on Sec. 27, T. 9, R. 4 W., in Yazoo County. It is about 14 feet in thickness, lies between two strata of green clay. . . . and extends all under the hill, cropping out again on the opposite side of it; it covers about one-fourth of the area of a square mile." I made a search for this bed but failed to find any trace or rumor of it.

At Freerun in the northern part of the county there is an outcrop of 11 inches of poor lignite in the valley behind Mr. Gunn's store. (Sample No. 19.) The analysis shows nearly 39 per cent of ash.

MADISON COUNTY.

"In Madison County lignite beds of great thickness have been struck in wells bored by order of the Rev. J. R. Lambuth, both at Canton and at his residence, Sec. 2, T. 7, R. 2 E., near Calhoun Station. At a depth of 375 feet a ledge of rock was penetrated, beneath which, for 46 feet, the auger brought up lignite, with only an occasional band of clay." (Hilgard, pp. 163, 192.) My inquiries at Canton failed to elicit any knowledge of lignite outcropping or in wells near by. A gentleman informed me that in the northeastern part of the county, between Couparle and Kirkwood, lignite was struck at about 40 feet in a well on Mr. J. R. Sherrard's land, and that it made a gas in the well so strong that the men could not work.

SCOTT COUNTY.

About 16 miles east of Canton on the further side of Pearl River in Scott (?) County there is a large vertical lignitic bank descending into the river. This is called Coal Bluff, and is reached by rowing on the river. The lower end of the outcrop dips sharply down stream and is merely stratified lignitic sand. At the highest point of the bluff

the strata are practically horizontal. At this point the section is about as follows:

Section at Coal Bluff, on Pearl River.

Columbia loam (?)	9 feet.
Unstratified sand	9 feet.
Lignitic shale	3¼ feet.
Solid lignite	17 inches.
Laminated lignite	3 feet.
Clay	x feet.

About 17 inches of this lignite is very solid. The strata vary considerably at different points. The thickest lignite, properly so called, is somewhat over 5 feet. Some of this bed is almost black. Part of the lignite near the water, and much of the underlying clay, is perforated or honey-combed with small holes. Sample No. 18 shows a high percentage of sulphur. The upper member of this section is marked doubtfully as Columbia. I could not reach it to examine it. Looked at from below it suggested Columbia, but that formation would scarcely be expected in a broad river bottom.

This lignite is very convenient for water transportation to Jackson. Mr. Wm. Richards reports considerable lignite above Alligator Lake, 2 miles further up the river.

Dr. Logan reports lignite and lignitic clay to the thickness of 6 feet in the Jackson formation at Morton.

HOLMES COUNTY.

The lignite beds of Holmes County compare favorably in thickness with any in the State, but in quality they do not seem to be equal on the whole of those of Calhoun County or of Choctaw County. The chemical analyses show both more sulphur and more ash than are to be found in the Calhoun County lignite. Analyses from four beds were made, the lowest showing 8426 B. T. U. and the highest 9201. Of these four beds the least thickness was 3 feet and the greatest 8.

On the old Stainback place now owned by Mr. G. F. Nixon, T. 14, R. 1 W., by following up a bluff stream, with pieces of lignite for my guide, I found a bed of fair lignite about 3 feet thick, shaling to some extent and breaking into blocks. Some of the blocks which had washed down stream seemed to stand weathering well. Below the main bed is a lens of unusually hard and bright lignite about 2 inches thick, preserving its woody structure and breaking evenly at right angles to the grain. Sample No. 20 included some of the latter.

The lignite rests on several feet of clay. Some distance from here in the bottom of the main stream is another stratum of apparently good lignite which seems to be about 2 feet thick.

Mr. Nixon informs me that there are three streams coming down the bluff on his place and that all bring down pieces of lignite.

A mile and a half west of Tolarville on land belonging to Mr. Henry Eakins' mother there is an outcrop of 4 feet of solid lignite high in volatile matter, but unfortunately gaining its solidity by inert earthy matter. This bed seems to be of considerable extent, both up and down the ravine. Mr. Eakin thinks the thickness persistent. (Sample No. 22.) Mr. Eakin reports that about 60 yards below this place the bed caught fire and burned 2½ years, and that it was finally extinguished by heavy rains.

In the ravine on the other side of the house some distance away there is a layer of 2 feet of mucky lignite. Mr. Eakin reports another outcrop of lignite ½ a mile north of here on the Mark Shettleworth place, which also burnt for some time.

An interesting bed of lignite is the one lying 6 miles southwest of Lexington to the west of the Ebenezer road. This bed has been on fire for some time; different people state different periods; a negro who lives near says he has known it to be burning for the past 12 years; others say 7 years, 5 years, etc. At present the lignite is burning at two different places some 40 yards apart. The mephitic fumes come up through joints in the Columbia loam, which is rendered too hot to be handled. I could see no flame, but both negroes and whites assure me that they have seen the fire. A negro living near the place says that he has seen the ravine lighted up at night like a little town. I let down a piece of rope a short distance, not to the lignite bed however by several feet, and the end of it was charred. All agree that in wet weather and in winter it burns more than in dry summer, which would seem to indicate a chemical action of water upon some material, yet there seems to be unmistakable evidence of fire. More probably the rainy season gives rise to more steam from the bed, which causes people to believe it is burning more in such weather. As has just been seen, in speaking of the bed near Tolarville, Mr. Eakin stated that the fire in that stratum was extinguished by heavy rains. The deposit around the vents and the odor from the burning indicate considerable sulphur. The ash indicates a heavy residue,

in some places even retaining the shaly stratified structure of the lignite. Much of the deposit has already been consumed.

This bed is 7⅓ feet thick where I measured it and probably a foot or two more at its greatest depth, but it soon becomes thinner in every direction. The lignite has abundant plant impressions and splits readily into thin flakes, in fact it seems almost impossible to get out good solid blocks of it. The edges that are exposed crumble badly. (Sample No. 21.) Below the lignite is a tough jointed clay.

On Rankin's Branch under a gravel bluff about 1 mile south of Howard occurs a stratum of lignite 2 feet thick, possibly thicker. This lignite contains veins of earthy matter, but otherwise seems good from a field examination of wet samples. The blocks in the branch appear to weather well. Following is the section:

	Feet
Columbia loam	7
Lafayette gravel, sand and clay	16
Solid lignite	2

As one ascends the hill toward Howard, an inch or two of lignite is seen cropping out above a blue clay.

At Shenoah Hill, 3 or 4 miles north of Howard and 2 or 3 miles east of Tchula on Mrs. Julia Harris's land, is one of the thickest beds of lignite I have seen in the State. This mine was opened several years ago and a quantity of lignite taken out; the old tunnel has since fallen in, so that it was dangerous to enter it. The fuel is still visible in part and is said to be 4 or 5 feet thick. Some of the larger lumps lying outside seem to have withstood weathering well; it was from one of these that sample No. 23 was taken. This sample upon analysis shows a high percentage of volatile matter and leaves comparatively little ash. Tried in the University forge, it gave a good welding heat and did not burn out too rapidly. The approach to this mine is easy and its location convenient to the railroad.

In the road near the old tunnel the lignite is again exposed, and also at several places up the ravine. A short distance up the ravine from the tunnel the stratum is 5 to 6 feet thick; still further up it is 2½ feet thick. Lignite is also said to show at two places across the ridge.

Above the lignite at the tunnel is a 2-foot stratum of excellent clay, an analysis of which is given in Table 13.

On the Pine Grove plantation Mr. McGee reports a 7-foot outcrop of lignite on the southeast side of the Funnigusha Creek.

Dr. Eugene Smith in his field notes of 1871 records a stratum of lignite 4 to 6 feet thick in Sec. 36, T. 15, R. 1 E. The seam of lignite was sometimes 2 feet above the bed of the branch, sometimes formed the bed of it. No doubt there are many other outcrops along the streams and ravines of the Bluff in this county. Fragments of lignite are not infrequently seen in the streams issuing at the foot of the Bluff.

In the northeastern corner of the county are some deposits of inferior lignite. I visited several outcrops on Mr. F. M. White's land 4 miles west of West, Sec. 24, T. 16, R. 4 E., and Mr. White also states that he struck lignite in several wells near his house. Sample No. 38 was taken from a spring about ¼ of a mile south of the house. I could not determine the thickness, but Mr. White says it is at least 3 feet. When dry this has a red earthy look. The analysis shows it to contain too much earthy matter and too little fixed carbon to be of any fuel value. Another bed on Mr. George Nabors' place seemed to be thin and impure.

CARROLL COUNTY.

I saw no lignite in Carroll County. I was told of its presence at Brock in the southeastern part of the county, but if it exists there it is probably no better than that in the northeastern part of Holmes County near it. Dr. Hilgard (p. 163) notes: "I have received specimens of iron pyrites, evidently derived from a lignite bed, from Carroll County, but have been unable to ascertain the locality, or particulars."

ANALYSES OF MISSISSIPPI LIGNITE.

SAMPLES AND ANALYSES.

About 50 samples of lignite were collected during the summer of 1906. In two or three cases it was not practicable for me to get the sample myself, in which cases I had to rely on others to collect the sample and send it to the University. It was the purpose to take representative samples throughout the thickness of the beds, but this could not always be done; often I had to take my samples wherever I could get them. After these samples had stood in the laboratory in open wooden boxes for several months smaller samples were selected from them and sent to the Agricultural and Mechanical College of Mississippi for chemical analyses. In selecting these smaller samples several different pieces were taken in each case and all large pieces of iron pyrites were excluded. The analyses were made in the laboratory of the Agriculture and Mechanical College under the direction of Dr. W. F. Hand. Here follows a table showing the analyses of the better Mississippi lignites; they are on an air-dried basis:

TABLE 5.

ANALYSES OF MISSISSIPPI LIGNITES.

(Dr. W. F. Hand, Analyst.)

No.	*Locality*	*Moisture*	*Volatile Matter*	*Fixed Carbon*	*Ash*	*Total*	*Sulphur*	*Calories*	*B.T.U.*
2	Panola Co., 1 m. from Tocowa .	13.93	44.65	35.17	6.25	100	.70	5,517	9,930
5	Itawamba Co., E. A. Palmer, II	12.51	36.55	38.44	12.50	100	3.27	4,928	8,870
6	Choctaw Co., W. A. Collins.....	11.44	36.57	38.56	13.43	100	2.05	5,115	9,207
7	Choctaw Co., Chester..........	11.39	39.79	38.72	10.10	100	2.83	5,236	9,425
8	Choctaw Co., Moses Bridges....	14.29	38.90	37.71	9.10	100	.86	5,018	9,032
9	Choctaw Co., Patrick Ray	10.79	41.59	36.54	11.08	100	1.18	5,311	9,560
10	Choctaw Co., E. W. Oswalt.....	11.61	34.61	42.47	11.31	100	2.66	5,595	10,071
11	Choctaw Co., Snow's field......	11.07	42.92	39.70	6.31	100	1.92	5,526	9,947
12	Winston Co., W. E. Huntley....	9.91	37.08	36.42	16.59	100	2.95	4,987	8,977
13	Winston Co., Drip Spring......	11.59	37.49	43.76	7.16	100	1.29	5,455	9,819
14	Winston Co., C. L. Taylor......	14.20	35.24	41.80	8.76	100	.63	5,255	9,459
15	Kemper Co., DeKalb	11.40	32.61	37.00	18.99	100	1.80	5,112	9,201
16	Kemper Co., Pool's mill........	13.61	37.14	42.10	7.15	100	2.64	5,439	9,790
17	Jasper Co., Garlandville........	12.51	41.40	33.93	12.16	100	2.77	5,050	9,090
18	Scott Co., Pearl River..........	13.50	39.66	36.50	10.34	100	4.10	4,972	8,950
20	Holmes Co., G. F. Nixon.......	13.20	40.16	32.24	15.40	100	1.20	5,050	9,090
21	Holmes Co., Burning bed.......	13.87	36.32	34.46	15.36	100	1.39	4,681	8,426
22	Holmes Co., Tolarville.........	10.07	41.71	22.86	25.36	100	1.64	4,831	8,696
23	Holmes Co., Shenoah Hill......	15.22	42.38	34.91	7.49	100	.91	5,112	9,201

TABLE 5—Continued.

ANALYSES OF MISSISSIPPI LIGNITES—Continued.

No.	Locality.	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	Sulphur	Calories	B. T. U
25	Panola Co., Tocowa	11.84	38.96	29.36	19.84	100	.69	4,706	8,471
27	Tate Co., Sarah	12.01	38.51	25.88	23.60	100	1.40	4,457	8,022
30	Benton Co., J. C. Orman	14.29	47.38	30.73	7.60	100	1.26	4,769	8,584
35	Lafayette Co., near Caswell	9.60	30.54	28.86	31.00	100	.57	4,021	7,238
39	Webster Co., 3 m. from Alva	13.04	36.68	35.62	14.66	100	.48	4,582	8,247
40	Webster Co., Bellefontaine	14.90	39.21	35.57	10.32	100	.56	5,065	9,117
42	Calhoun Co., Pittsboro	13.96	39.97	38.58	7.49	100	.56	5,190	9,342
43	Calhoun Co., Camp Spring	12.20	46.27	30.86	10.67	100	.76	5,096	9,173
44	Calhoun Co., John McPhail	11.46	40.74	37.59	10.21	100	.78	5,486	9,875
45	Calhoun Co., near Slate Spring	12.26	37.43	41.94	6.37	100	.94	5,533	9,959
46	Yalobusha Co., J. J. Milton	12.62	40.85	39.94	6.59	100	2.05	5,392	9,706
47	Lafayette Co., W. J. Hogan	11.84	34.15	35.68	18.33	100	.48	4,598	8,276
48	Lafayette Co., near Delay	14.61	38.51	39.10	7.78	100	1.28	5,221	9,398
50	Lafayette Co., R. V. Edwards	14.60	38.59	35.21	11.60	100	1.83	4,878	8,780

INTERPRETATION OF THE TABLE.

These analyses need no comment for the geologist or for the chemist, but a few words of explanation may be helpful for the general reader, for whom primarily this report is intended. The constituent parts are shown in the first four columns of the table, the sum of these four giving a total of 100 per cent. The second and third columns show the useful or combustible constituents, the volatile matter and the fixed carbon. The first and fourth columns show the worthless or non-combustible parts of the lignite, namely the moisture or water and the ash or inert matter left after burning. By observing the relative proportion of combustible and non-combustible constituents one gets an idea of the value of the lignite. The readiest way to do this however is to glance at the last column in the table, which shows the B. T. U., or British thermal units, per pound; the higher the B. T. U. the greater the heating capacity of the lignite in general. The calories may be found by dividing the B. T. U. by 1.8. The sulphur, which is an impurity in coal or lignite, has been determined separately and recorded in another column.

MISSISSIPPI LIGNITES COMPARED WITH OTHERS.

By comparing these analyses with those of the lignite of other States, made by the U. S. Geological Survey at St. Louis, it will be seen that the better Mississippi lignites are the equal of the brown lignites of North Dakota and Texas, and are not very greatly inferior to the black lignites of Colorado, Montana and Wyoming.

TABLE 6.

COMPARATIVE ANALYSES OF LIGNITES.

(By U. S. Geol. Survey and Dr. W. F. Hand.)

No.	*State*	*Moisture*	*Volatile Matter*	*Fixed Carbon*	*Ash*	*S*	*B. T. U.*
1	North Dakota...	10.03	38.12	39.95	11.90	1.76	9,562
2	North Dakota...	12.01	40.62	39.36	8.01	1.08	9,693
1	Texas..........	13.40	42.75	29.00	14.85	1.04	9,358
2	Texas..........	24.48	38.17	28.94	8.41	.53	8,489
10	Mississippi.......	11.61	34.61	42.47	11.31	2.66	10,071
13	Mississippi.......	11.59	37.49	43.76	7.16	1.29	9,819
23	Mississippi.......	15.22	42.38	34.91	7.49	.91	9,201
44	Mississippi.......	11.46	40.74	37.59	10.21	.78	9,875
48	Mississippi.......	14.61	38.51	39.10	7.78	1.28	9,398
1	Colorado........	16.77	35.18	44.29	3.76	.54	10,652
1	Montana........	9.05	36.70	43.03	11.22	1.76	10 777
1	Wyoming.......	17.89	37.81	40.75	3.55	.63	10,310

This table includes all the lignite analyses recorded by the Coal-testing Plant at St. Louis which carried with them a determination of the B. T. U. A few other analyses of North Dakota and Texas lignite records on page 264 seem to be no better. However, in Dr. Wilder's reports on the North Dakota lignites, where a much larger number of analyses are given, there are many lignites which show 43 to 45 per cent of fixed carbon, and a few 47 per cent. The calorific values were not determined. Only five lignites in the Mississippi list show above 40 per cent of fixed carbon, the highest being 43.76 per cent. The five lignites in Table 6 represent as many different counties, and with one exception are the best in their respective counties.

WORTHLESS LIGNITES.

For the sake of completeness of record there is given below a table of analyses of inferior or worthless lignites, samples of which were collected during the past summer:

TABLE 7.

ANALYSES OF INFERIOR OR WORTHLESS LIGNITES.

(W F. Hand, Analyst.)

No.	*Locality*	*Moisture*	*Volatile Matter*	*Fixed Carbon*	*Ash*	*S*
3	Itawamba Co., 4¾ m. from Fulton.........	11.55	33.70	29.52	25.23	3.27
4	Itawamba Co., E. A. Palmer, I...........	8.48	16.67	13.81	61.04	2.81
19	Yazoo Co., Freerun	8.72	34.64	22.84	33.80	2.76
24	Tallahatchie Co., B. M. Baker	10.45	32.20	30.64	26.71	6.16
31	Benton Co., J. D. Rutledge...............	7.48	23.75	20.74	48.03	.53
32	Benton Co., Shelby Cr. Church...........	5.54	19.81	11.06	63.59	3.02
33	Lafayette Co., Billingsley's shop	7.42	20.94	22.43	49.21	.87
34	Lafayette Co., Tallahatchie River	9.35	25.35	20.50	44.80	2.09
37	Lafayette Co., Old Wyatte................	9.82	24.56	26.41	39.21	1.63
38	Holmes Co., near West..................	7.24	38.49	14.06	40.21	.76

MOISTURE.

The moisture in the air-dried samples, as will be seen by a reference to Table 5, ranges from 9.60 to 15.22 per cent. The average moisture of the 33 samples given in that table is 12.58 per cent. This denotes the moisture left in the samples after they have been dried in the air without artificial heat. When taken fresh from the earth they contain much more moisture. Many of the Mississippi lignites lie below strata of sand and thus become saturated with the water which percolates through these strata. Springs are often found flowing out just above the beds of lignite or from the beds themselves. I took no sealed samples from the lignite beds myself, but after I had finished my field work I wrote back for nine samples from as many of the best or most convenient deposits. I requested that duplicate samples be sealed in Mason fruit jars at the outcrops immediately upon removal from the strata, giving such instruction for obtaining the samples as I hoped would make the conditions of collecting as nearly uniform as possible. One of these sets of sealed samples was sent to the Agricultural and Mechanical College of Mississippi, the other to the Geological Survey of Illinois. Below are tabulated the results of the moisture determinations from these samples:

TABLE 8.

MOISTURE IN FRESH LIGNITES.

(Determinations by Dr. W. F. Hand and Dr. S. W. Parr.)

No.	*Locality*	*A. & M. Coll. of Miss. (By Dr. W. F. Hand.)*			*Geol. Survey of Ill. (By Dr. S. W. Parr.) Total.*
		Air-dried	*Further dried at 110°*	*Total*	
14	Winston Co., C. L. Taylor...	27.32	22.35	49.67	48.70
23	Holmes Co., Shenoah Hill...	10.45	21.35	31.80	43.40
25	Panola Co., Tocowa........	11.15	21.05	32.20	47.91
43	Calhoun Co., Camp Spring...	24.20	19.70	43.90	44.09
46	Yalobusha Co., J. J. Milton..	10.19	15.26	25.45	49.25
48	Lafayette Co., near Delay...	31.33		31.33	50.66
50	Lafayette Co.,R. V. Edwards	25.54		25.54	51.58

The average of the total moisture in the fresh samples according to Dr. Hand's determination is 34.27 per cent, according to Dr. Parr's determination it is 47.8 per cent. Dr. Wilder found the average for a

large number of North Dakota samples to be 30 per cent. Thus it will be seen that the moisture in lignite is a serious consideration, especially in transportation, for a large part of the expense of transportation is for hauling useless water.

ASH.

Some of the Mississippi lignites leave comparatively little ash upon burning, while others leave a rather high percentage. See Table 5. The average of the 33 lignites in that table is 12.5 per cent of ash, or leaving out the three impurest the average of 30 samples is 11 per cent of ash. The average of the seven brown lignites from North Dakota and Texas, determined by the U. S. Geological Survey at St. Louis, is 12.7 of ash. From these purer lignites shown in Table 5 there are all grades of impurity to mere lignitic shales and clays. See Table 7. The earthy impurity which makes ash may occur in lignite in two ways; first, thoroughly disseminated throughout the mass; second, deposited in the cracks, fissures and laminæ of the lignite as bands of clay, sand or other earthy matter. In the latter case the impurity is readily observed in a dry specimen, in the former it is often difficult of detection without an analysis.

The composition of the ash from the lignites may be seen from the following table:

TABLE 9.

ANALYSES OF ASH FROM LIGNITE.

(Dr. W. F. Hand, Analyst.)

No. of Lignite	14	23	25	43	46	48	50
Silicon dioxide (SiO_2)	29.10	22.95	63.85	51.82	35.00	22.66	35.10
Aluminum oxide (Al_2O_3)	13.45	12.37	13.25	26.98	17.00	14.88	15.23
Iron oxide (Fe_2O_3)	21.00	19.00	10.95	7.12	29.00	20.62	23.35
Calcium oxide (CaO)	22.80	21.37	2.50	6.07	4.55	15.20	8.62
Magnesium oxide (MgO)	.19	.97	.90	.22	1.50	2.90	1.99
Sulphur trioxide (SO_3)	8.53	14.70	4.46	5.45	6.34	19.89	12.30
Undetermined	4.93	8.64	4.09	2.34	6.61	3.85	3.41
Total	100	100	100	100	100	100	100

Hilgard (p. 161) gives the following analysis of the ash from a lignite found on Hughes' Branch on the edge of the Potlockney bottom, Lafayette County:

Analysis of Ash of Lignite from Hughes' Branch.

Insoluble matter (sand and silex)	59.24
Potash	trace.
Soda	2.52
Lime	8.83
Magnesia	.73
Oxide of iron, and alumina	25.79
Chloride, carbonic and sulphuric acids, and loss	2.89
	100

SULPHUR.

The percentage of sulphur in the lignites may be seen by a reference to Table 5. In some of the samples, especially those from Calhoun and Webster Counties, it is very small; in others it is larger, two samples showing over 3 per cent. The average of the 33 samples is 1.53 per cent; leaving out three samples which contain more than $\frac{1}{5}$ of the whole amount the average of 30 samples is 1.32 per cent. This seems to be considerably larger than the average for the North Dakota lignites. Five analyses of Nebraska lignites made by Mr. Ernest F. Burchard (p. 280) show an average of 1.16 per cent of sulphur. Many good coals show a higher percentage of sulphur than the Mississippi lignites.

SPECIFIC GRAVITY.

The specific gravity of a few of the lignites was determined. The results, showing an average specific gravity of 1.422, are tabulated below:

TABLE 10.

SPECIFIC GRAVITY OF LIGNITES.

(Determinations by Dr. W. F. Hand.)

No.	*Locality*	*Specific Gravity*
14	Winston Co., C. L. Taylor	1.453
23	Holmes Co., Shenoah Hill	1.326
25	Panola Co., Tocowa	1.415
43	Calhoun Co., Camp Spring	1.433
46	Yalobusha Co., J. J. Milton	1.452
48	Lafayette Co., Delay	1.452
50	Lafayette Co., R. V. Edwards	1.425

Burchard (p. 279) gives the specific gravity of Nebraska lignites, after having dried in the air, as 1.28 to 1.35.

ANALYSES BY DR. PARR.

The following analyses made by Dr. S. W. Parr of the University of Illinois were sent to me after this report had gone to the printer; hence full use of the data could not be made in the preceding pages. The method of collecting the seven samples sent to him has already been described under the head of Moisture. It will be observed that he first determined the total amount of moisture in the samples as received, and then determined the other constituents on a dry basis. The British thermal units were determined with the Mahler apparatus. The fact that they seem so much higher than in the other analyses is due to the difference in method of analyses, Dr. Parr having used thoroughly dried lignite and Dr. Hand air-dried lignite. Averages are given in the last line of the table.

TABLE 11.

ANALYSES OF MISSISSIPPI LIGNITES.

(Dr. S. W. Parr, Analyst.)

No.	*Total Moisture*	*Analyses of dry lignite*					
		Carbon	*Available Hydrogen*	*Ash*	*Sulphur*	*Calories*	*B. T. U.*
14	48.70	60.56	1.85	12.55	.76	5,548	9,986
23	43.40	59.10	2.70	14.44	.84	5,728	10,310
25	47.91	59.70	2.42	12.48	.73	5,676	10,217
43	44.09	58.83	1.86	13.35	4.18	5,488	9,878
46	49.25	64.90	2.55	5.23	1.17	6,149	11,068
48	50.66	62.96	2.03	9.00	1.28	5,815	10,467
50	51.58	57.38	1.76	13.08	2.00	5,289	9,520
Av.	47.80	60.49	2.17	11.44	1.56	5,670	10,206

USES OF LIGNITE.

GENERAL.

It would seem both from analyses and from experience that the better qualities of lignites may be used for practically all the purposes for which bituminous coal may be employed. One exception should be made to this statement; most of the lignites are unsuitable for coking. Lignite has long been in use in Germany and other European countries, and is at present being used in North Dakota, Nebraska, Texas and other parts of the United States. It should be remembered in substituting lignite for coal that modifications of fire-boxes and furnaces are sometimes desirable.

IN OPEN GRATES.

Some of the better qualities of lignite when dry produce a good steady fire in the open grate. For this purpose a chimney of good draft is desirable, otherwise disagreeable fumes may escape into the room. No series of tests of Mississippi lignites in the open grate were conducted by the Survey. The writer however tried in his own study a scuttle of fuel composed of Calhoun County lignites and obtained a very steady satisfactory fire which burnt up completely, leaving no clinkers in the grate. The four lignites which composed this fire were Nos. 42–45; by referring to Table 5 it will be seen that they contain very little sulphur, and less than the usual amount of ash, and that they all run above 9,100 B. T. U. In case of poorer qualities of lignite the addition of a little wood or stone coal would be helpful.

IN STOVES.

Good lignite may take the place of wood and coal in stoves both for heating and cooking. The same precaution should be taken as in the case of stone coal, namely to see that there are no leaks, otherwise troublesome gases may escape into the room. Mr. Thomas Pettigrew, engineer for the asylum at Jamestown, North Dakota, writes: "The use of lignite coal at this institution started in 1890. Since that time we have used it continually for generating steam, and for the past

eight years have used it exclusively for cooking in the general kitchen of the institution. Lignite coal can be burned in any furnace that burns hard or soft coal." (Sec. Bien. Report, p. 176.) Many of the large stove factories now have on the market stoves especially designed for using lignite.

IN THE FORGE.

Any of the medium lignites will give in the forge a heat sufficient for sharpening plows and drawing iron, and the better qualities will give a welding heat. Some of the failures of lignite in the forge reported in this State were no doubt due to the fact that the lignite was used too "green" or wet. The admixture of a small quantity of charcoal or bituminous coal is recommended in case the dry lignite fails to give satisfactory results. I had the following four lignites tried in the University shop under my observation:

TABLE 12.

LIGNITES TRIED IN THE FORGE.

No.	*County*	*Moisture*	*Volatile Matter*	*Fixed Carbon*	*Ash*	*Sulphur*	*B. T. U.*
10	Choctaw..........	11.61	34.61	42.47	11.31	2.66	10,071
23	Holmes...........	15.22	42.38	34.91	7.49	.91	9,201
40	Webster..........	14.90	39.21	35.57	10.32	.56	9,117
50	Lafayette.........	14.60	38.59	35.21	11.60	1.83	8,780

The samples were the laboratory specimens which had been indoors for nine months. All four gave a good weld. No. 50 was chosen especially because of its comparatively low B. T. U.; the result however was satisfactory. All gave off sparks, showing that some of the matter was being blown away by the blast from the bellows.

FOR BURNING BRICK.

Lignite is used in North Dakota for burning brick at Dickinson, Williston, Washburn, Burlington, New Salem and other places. The results obtained are 1,000 red bricks burnt at a temperature of 1,500 degrees with 1,500 pounds of lignite. In some of these plants forced draft is used, in others only natural draft. (Wilder, Sec. Bien. Report,

p. 185.) In Mississippi there are many excellent brick clays in the vicinity of lignite deposits. Doubtless there are also some good pottery clays near the Mississippi lignite beds. Three samples of clays associated with the Holmes County lignites were analyzed with the results given in Table No. 13. Clay No. 1 occurs with lignite No. 20; clay No. 2 occurs with lignite No. 21; and clay No. 3 occurs with lignite No. 23. Clay No. 3, associated with the Shenoah Hill lignite, is of excellent quality and would doubtless make good fire brick. The other two samples contain rather high percentages of iron oxide which would cause them to burn red.

TABLE 13.

ANALYSES OF CLAYS ASSOCIATED WITH HOLMES COUNTY LIGNITES.

(W. F. Hand, Analyst.)

Constituents.	1	2	3
Silicon dioxide (SiO_2)	68.64	68.56	69.67
Aluminum oxide (Al_2O_3)	11.62	9.77	17.43
Iron oxide (Fe_2O_3)	5.95	9.07	2.82
Lime oxide (CaO)	1.43	1.25	.68
Magnesium oxide (MgO)	1.53	1.30	.24
Sulphur trioxide (SO_3)	0.00	0.00	tr.
Volatile matter (CO_2)	7.25	6.32	6.70
Moisture	3.52	3.60	2.32

UNDER BOILERS.

Lignite is successfully used for direct firing under boilers. In some cases forced drafts are used, in others the natural draft is relied upon. Automatic stokers are to be recommended when large quantities of fine lignite are used, and in the case of dry powdered lignite the fuel might be introduced by means of a blast. When feeding fresh or "green" lignite it is desirable to fire only one side of the furnace at a time, as the high percentage of moisture tends to reduce the heat temporarily. Special modifications of furnaces are sometimes used for burning lignite; the purpose being to bring the volatile matter to a combustion heat before it escapes. One of these devices is an arch of fire brick built over the front of the firebox, which standing at a high heat ignites the gases about it.

No boiler tests of the Mississippi lignite have yet been conducted. I quote the results of a comparative test made in August, 1894, by engineer Thomas Pettigrew between Youghiogheny coal and Dakota lignite. (Wilder, p. 19.)

TABLE 14.

LIGNITE TEST AT JAMESTOWN, NORTH DAKOTA.

(By Thomas Pettigrew.)

	Youghiogheny coal, Aug. 6, 1894.	*Lignite coal, Aug. 8, 1894.*
Duration of test, hours	$7\frac{1}{2}$	8
Average temperature of feed water, °F	74	74
Coal burned, pounds	1,400	3,370
Combustible, pounds	1,243	3,170
Ash, per cent	11.21	5.93
Coal burned per square foot of grate per hour, pounds	8.29	18.72
Water evaporated at temperature of feed, pounds	8,837	14,157
Water evaporated in pounds per pound of coal, actual condition	6.312	4.2
Water evaporated in pounds per pound of combustible	7.1	4.46
Temperature of flue gases, °F	510	510
Value of coal	$1.00	$0.665

Boiler 6 feet in diameter by 16 feet long, with 30 $4\frac{1}{2}$-inch flues; grate surface 4 feet 5 inches by 5 feet; coal 3 days from mine; cost of Youghiogheny lump at Jamestown, $6.80, of lignite, $2.80.

This with other tests goes to show that Dakota lignite has about 63 per cent of the evaporative power of Youghiogheny coal, 70 per cent of that of Missouri coal, and 75 per cent of Iowa coal. Considering the relative cost of lignite and coal it will be seen that economy may be on the side of lignite.

The following comparative table between bituminous coal and lignite under the boiler is compiled from the report of the tests made by the Coal-testing Plant of the United States Geological Survey at St. Louis in 1904:

TABLE 15.

COMPARATIVE TESTS OF COAL AND LIGNITE.

(By the U. S. Geological Survey.)

No.	*Kind*	*Locality*	*Water evaporated per hr. (in lbs.).*	*Horsepower developed*
2	Bituminous coal	Carbon Hill, Alabama	6,335	216.4
4	Bituminous coal	Wheatcraft, Kentucky	6,076	211.7
2	Bituminous coal	Bonanza, Arkansas	5,268	180.5
1	Black lignite	Wyoming	5,355	186.6
1	Black lignite	Colorado	4,311	151.0
1	Brown lignite	North Dakota	3,175	108.9
1	Lignite briquettes	Texas	1,666	57.3

The North Dakota lignite used in this test has a calorific value considerably below that of many of the Mississippi lignites.

BY BRIQUETTING.

Lignite and waste coal have long been made into briquettes in Germany and other European countries where fuel is scarce and consequently dear. By this process the waste products of mines are converted into firm hard fuel, which may be handled and burned as any other coal. Mechanical pressure is employed and generally some binding material is mixed with the powdered coal or lignite, such as pitch of various kinds, asphalt, creosote, tar, rosin, petroleum, molasses and milk of lime. It is desirable that if possible the bond should be combustible and thus add to the fuel value of the briquettes.

Specimens of Texas brown lignite were sent by Dumble (p. 223) to Europe to be tested for briquettes. The results were unsatisfactory when pressure alone was used, but were entirely satisfactory when bond was employed. A sample of lignite from Pike Co., Alabama, was sent to a briquetting syndicate in Germany and molded into briquettes with entire success. Some of these briquettes, which look much like anthracite coal, may be seen at Tuscaloosa. (Smith, private letter.)

Several experiments in briquetting American lignites with various kinds of pitch were tried by the Coal-testing Plant at St. Louis, some of which were successful and some of which were not. The following table is compiled from the report of that plant:

TABLE 16.

EXPERIMENTS IN BRIQUETTING LIGNITE.

(By U. S. Geological Survey.)

No.	*Kind*	*Locality*	*Per cent of pitch*	*General character*	*Behavior on weathering*	*Behavior on burning*
1	Black	Colorado......	10	Hard and lustrous, but brittle	Slight deterioration..........	Satisfactory, little disintegration.
1	Black	New Mexico...	12	Very unsatisfactory..........	Crumbles........	Disintegrates.
2	Black	New Mexico...	7	Crumbly........	Disintegrates....	Disintegrates.
1	Brown	North Dakota.	10	Porous, little cohesion.........	Disintegrates....	Disintegrates.
1	Black	Wyoming.....	9	Fair, porous.....	Fair............	Satisfactory.

BY COKING.

Some varieties of lignite are said to yield a coke which can be used in the production of iron. The great majority, however, do not fuse sufficiently in the oven to produce coke. Even the excellent black lignite or subbituminous Laramie coal of the Marshall district in Colorado has not been successfully used for coke. No experiments with a view to coking have been made on the Mississippi lignites, but it is highly improbable that they could be utilized advantageously in that way without the addition of some other material. Dumble (p. 231) concludes that certain varieties of Texas brown coal will form a coke, if charred, with bond of caking coal and coal tar pitch, which, even if it should not prove sufficiently firm for the blast furnace, will nevertheless answer for fuel for locomotives and for other similar purposes.

FOR ILLUMINATING GAS.

Lignite may be used for the manufacture of illuminating gas, and has been so used to some extent on the continent of Europe. Some of the Mississippi specimens run quite high in volatile matter, one having more than 47 per cent in the air-dried sample; others are high in fixed carbon. Burchard (pp. 280, 281) found lignite from Dakota County, Nebraska, to yield 12,279 cubic feet of gas per ton; this was the average result of ten tests. This is as high a yield as the cannel coals and considerably higher than the bituminous coals which he quotes. The lignite he used was comparatively low in volatile matter and high in fixed carbon. He found the illuminating power of the gas weak, however, and suggested that it would need enriching to make a good illuminant. Dumble (p. 227) considers many of the Texas brown coals capable of producing illuminating gas.

FOR PRODUCER GAS.

Recently it has been shown that the brown lignites make excellent producer gas. The Coal-testing Plant of the U. S. Geological Survey at St. Louis conducted a series of experiments upon bituminous coals and lignites with most gratifying results. The brown lignites tested came from North Dakota and Texas and are no better than many of the Mississippi lignites, and are inferior to some of them. The results

of some of these tests may be seen in the two following tables. The first shows a comparison of tests of coal made with the boiler and the gas-producer; the second shows a comparison between bituminous coal and brown lignite in the gas producer:

TABLE 17.

COMPARATIVE TESTS WITH BOILER AND GAS-PRODUCER.

(Reduced from Coal-testing Plant Report, p. 978.)

Coal	*Lbs. of coal burned per sq. ft. of grate surface per hour*		*B. T. U. per lb. of coal used*		*Electrical horse-power delivered to switch-board*		*Lbs. of coal per electrical horse-power per hour*	
	Boiler plant	*Gas producer*	*Boiler plant*	*Gas producer*	*Boiler plant*	*Gas producer*	*Boiler plant*	*Gas producer*
Alabama, No. 2	21.54	7.78	12,555	13,365	213.7	200.6	4.08	1.64
Colorado, No. 1	17.80	7.56	12,577	12,245	149.1	200.2	4.84	1.71
Ilinois, No. 3	21.23	8.41	12,857	13,041	198.1	199.6	4.34	1.79
Indiana, No. 1	22.39	9.08	13,377	13,037	220.0	199.9	4.13	1.93
Kentucky, No. 3	21.75	8.92	13,036	13,226	208.9	200.5	4.22	1.91
Missouri, No. 2	25.00	7.96	11,500	11,882	205.6	198.6	4.93	1.71
West Virginia, No. 1	18.94	7.36	14,198	14,396	196.7	200.4	3.90	1.57
Wyoming, No. 2	26.51	9.50	10,897	10,656	182.0	201.2	5.90	2.07

TABLE 18.

PRODUCER-GAS TESTS OF COALS AND LIGNITES.

(Reduced from Coal-testing Plant Report, pp. 1,316–23.)

Sample	*Cubic ft. of gas per lb. of dry coal.*	*B. T. U. per lb. of dry coal*	*B. T. U. per cubic ft. of gas*	*Lbs. of dry coal per electric h'se-power per hour*
Alabama, No. 2, bituminous	60.4	13,365	149.2	1.64
Illinois, No. 3, bituminous	53.9	13,041	154.8	1.79
Kentucky, No. 3, bituminous	55.1	13,226	155.9	1.91
North Dakota, No. 2, lignite	41.5	11,255	188.5	2.29
Texas, No. 1, brown lignite	42.7	10,928	169.7	2.22
Texas, No. 2, brown lignite	51.6	11,086	156.2	1.71

I quote a summary of the results from the report of the committee in charge of these tests at St. Louis (pp. 29, 30):

"Probably the most important of the results accomplished has been the demonstration that bituminous coals and lignites can be used in the manufacture of producer gas, and that this gas may be consumed in internal-combustion engines for the development of power, with a fuel economy of over 50 per cent. The use of producer gas made from

anthracite coal, from coke, or from charcoal for power purposes, and of producer gas from bituminous coal in steel works, etc., is no new story; but the demonstration of the possibility of utilizing bituminous coal and lignite in the gas engine is a decided advance in the economical combustion of coal for power. It has been shown by comparative tests that the power-producing efficiency of a number of bituminous coals, when converted into gas and used in the gas engine, is 2½ times what it is when used under boilers in the production of steam power. In other words, 1 ton of coal used in the gas-producer plant has developed, on a commercial scale, as much power as 2½ tons of the same coal used under Heine boilers with a simple Corliss engine. The results were measured by the amount of electrical horsepower per hour delivered at the switchboard.

"Of scarcely less importance are the results obtained in the use of lignite in the gas-producer plant. It has been shown that a gas of higher quality can be obtained from lignite than from high-grade bituminous coals, and that 1 ton of lignite used in a gas-producer plant will yield as much power as the best Pennsylvania or West Virginia bituminous coals used under boilers. It appears, in fact that as coals decline in value when measured by their steam-raising power, they increase in value comparatively as a fuel for the gas producer. The brown lignites on which tests were made at the coal-testing plant were from North Dakota and Texas, and the unexpectedly high power-producing qualities developed by them in the gas producer and gas engine give promise of large future developments in these and other States in the far West, where extensive but almost untouched beds of lignite are known to exist."

The character of the gas produced by lignites in the gas producer may be seen from the following analyses taken from the same report (p. 1,323):

TABLE 19.

ANALYSES OF PRODUCER GAS FROM LIGNITE.

(By U. S. Geological Survey.)

Average composition of gas by volume.

Gas	*Brown Lignites*		
	N. Dakota No. 2	*Texas No. 1*	*Texas No. 2*
Carbonic acid (Co_2)......	8.69	11.10	9.60
Oxygen (O_2)............	.23	.22	.20
Carbonic oxide (CO).....	20.90	14.43	18.22
Hydrogen (H_2)..........	14.33	10.54	9.63
Marsh gas (CH_4)........	4.85	7.48	4.81
Nitrogen (N_2)...........	51.02	56.22	57.53
Total............	100.02	99.99	99.99

FOR TAR .

Tar may be made from lignite as from bituminous coal. It is obtained as a by-product in the manufacture of gas from lignite.

FOR FERTILIZER.

For several years a Meridian company used the lignite from Russell, Lauderdale County, as a constituent in the manufacture of a land fertilizer; this has since been abandoned, presumably because it was not sufficiently rich in fertilizing elements. It may well be doubted whether lignite has sufficient fertilizing value to make it of economic importance to the farmer, except perhaps locally on the farms where it occurs. In case of its local use it would be prudent to experiment with it before using it very heavily, or else by chemical examination determine that the ash does not contain enough noxious constituents to be harmful to the crops.

ACKNOWLEDGMENTS.

A list of some of the more important works bearing on Mississippi geology and on American lignite is given in the bibliography. To most of these I am indebted and to several of them deeply indebted. I wish to thank Mr. A. F. Crider, Director of the State Geological Survey of Mississippi, for many valuable suggestions and for a kindly interest in this report from the beginning of the field work to the completion of the printing. To Dr. W. F. Hand of the Agricultural and Mechanical College of Mississippi I owe the general direction and supervision of the lignite analyses. To Dr. S. W. Parr of the University of Illinois I am indebted for seven additional analyses of lignite. To many people throughout the State who gave me the benefit of their knowledge of local outcrops and showed me other courtesies during the progress of the field work I am under deep obligations.

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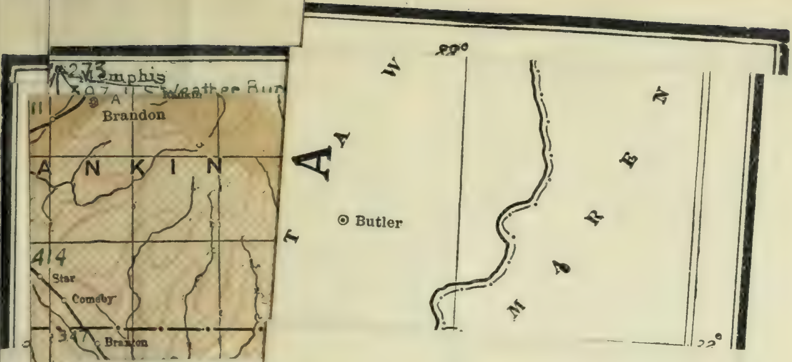

Selma chalk

BRANDON NASHVILLE

Eutaw s

STATE GEOLOGICAL SURVEY
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A. A. KINCANNON,
J. C. HARDY,
Commissioners
A. F. CRIDER, Director.
A PROVISIONAL
GEOLOGIC AND TOPOGRAPHIC MAP
OF MISSISSIPPI
This map represents the present knowledge of the geologic boundaries of Mississippi. It has been compiled from hitherto published sources and recent investigations. Special acknowledgments are due Dr. E. W. Hilgard of the former State Survey, and recent publications of the U. S. Geological Survey. The map shows the general outline of the formations, and the topography of the State as determined by the railroad and government elevations. Changes will be necessary as the work of the survey progresses and more detailed work is done.
Scale of Miles
LEGEND
ECONOMIC PRODUCTS
QUATERNARY
Port Hudson and Recent alluvium
Clay loam for making common brick, tiling and road ballast.
Loess loam
Loam for making common brick and tiling.
TERTIARY
Grand Gulf sandstone and clays
Sandstone for building purposes, clays for common brick and fire brick.
Vicksburg limestone
Limestone for making Portland cement and lime.
Jackson clays and sands
Clay marls for making Portland cement; sands for building and moulding purposes.
Claiborne-Lisbon clays and sands
Of little economic importance.
Claiborne-Tallahatta buhrstone
Stone for road making and ballast.
Wilcox clays and sands
Workable veins of lignite; sands for moulding, building, and making glass; clays for making pottery, fire brick and fancy face brick.
Midway limestone and clays
Clay for making drain tile, and for mixing with the Selma chalk for making Portland cement.
CRETACEOUS
Of little economic importance.
Limestone suitable for making Portland cement and lime.
Selma chalk
Building and moulding sand.
Clays for pottery, tiling, fire brick and face brick.
Shales and clays for making paving brick, sewer pipe and tiling; limestone for lime, building stone, road making, natural and Portland cement, sandstone for building stone and glass.
LIGNITE OUTCROPS.
BRICK AND TILE PLANTS.

Mississippi State Geological Survey

ALBERT F. CRIDER, DIRECTOR.

BULLETIN No. 4

CLAYS OF MISSISSIPPI

PART II.

Brick Clays and Clay Industry of Southern Mississippi

By WILLIAM N. LOGAN

1908

BRANDON-NASHVILLE

STATE GEOLOGICAL COMMISSION.

His Excellency, E. F. Noel........................... *Governor*
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E. N. Lowe................................. *Assistant Geologist*

LETTER OF TRANSMITTAL.

Governor E. F. Noel, Chairman, and Members of the Geological Commission:

GENTLEMEN:—I submit herewith a report on the brick clays of southern Mississippi, prepared by Dr. W. N. Logan, and recommend that it be printed as Bulletin No. 4. A report on the brick clays of northern Mississippi was published in 1907 as Bulletin No. 2. In that report considerable attention was given to the origin and technology of clays as well as to the status of the brick industry of northern Mississippi. Bulletin No. 4 completes the study of the brick clays of the State and should be read in connection with Bulletin No. 2.

The common brick clays contribute largely to the industrial development of the State, and their importance will become greater year by year as the valuable timber becomes scarce.

Dr. Logan has pointed out in his report that the brick industry, especially in southern Mississippi, is yet in its infancy. Many of the plants are small and rather crude methods are employed in the manufacture of brick. This condition will gradually change for the better as the demand for brick increases. In most of the large towns up-to-date plants have been erected to meet the growing demands for a substantial building material.

The brick clays of southern Mississippi, east of Pearl River are, as a general rule, more difficult to handle than those west of Pearl River and in northern Mississippi. Some of the plants have suspended operations because it is so difficult to dry and burn the brick without cracking. As pointed out by Dr. Logan, this trouble can be largely overcome by mixing the tough plastic clay with coarse, sharp sand, and storing the mixture in covered sheds and allowing it to weather thoroughly before using.

Very respectfully,

A. F. CRIDER, *Director.*

Jackson, Mississippi, August 1, 1908.

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INTRODUCTION.

In the year 1906 the writer began the investigation of the brick-clays of Mississippi in connection with the State Geological Survey. The work of the first season was confined to the territory lying north of the Alabama and Vicksburg Railroad. The results of these investigations were published in 1907 in a report entitled, "Brick Clays and Clay Industry of Northern Mississippi." The report includes a discussion of the technology of clays; a report on the geology of clays, and also a discussion of the brick industry of northern Mississippi.

The present report includes a discussion of the geology of the brick-clays and clay industry in the counties lying south of the Alabama and Vicksburg Railroad. The brick industry in many of these counties is either entirely undeveloped or only in an experimental stage. In some of the counties, however, bricks have been manufactured successfully for many years. As this section of the State is undergoing a rapid industrial development, and as it is dependent largely upon brick for building material of a more permanent class, we may expect that the brick industry in southern Mississippi will be greatly developed in the near future. This preliminary report should be read in connection with the one mentioned above.

The counties which are included in the report are as follows:

Adams	Franklin	Jefferson Davis	Pearl River
Amite	Greene	Jones	Pike
Claiborne	Hancock	Lamar	Simpson
Clarke	Harrison	Lawrence	Smith
Copiah	Jackson	Lincoln	Wayne
Covington	Jasper	Marion	Wilkinson
Forrest	Jefferson	Perry	

GEOLOGICAL FORMATIONS.

The geological formations of southern Mississippi are the Claiborne, the Jackson, the Vicksburg, the Grand Gulf (including the Pascagoula), the Lafayette, the Port Hudson, the Loess and the Columbia.

Claiborne.—The outcrop of the Claiborne extends in a belt across the State, the northern boundary running from the northern part of

Clarke County to the southern part of Grenada County. The width of the outcrop increases toward the northwest. West of Grenada County the formation is concealed by the alluvial deposits of the Yazoo basin, and it has never been found in the hills north of Grenada County.

The Claiborne represents one of the stages of the Eocene epoch of the Tertiary period. In Mississippi the Claiborne has been divided into the Tallahatta buhrstone, the Lisbon and the undifferentiated Claiborne.

The Tallahatta buhrstone consists, in some localities, of hard, white sandstones and claystones. In other localities the formation is composed largely of ferruginous sands but slightly cemented, and containing numerous fossils. In some places the rocks are cherty in character, with layers of chert interbedded with sandy clays.

The Lisbon formation consists of sands, usually white, containing calcareous material. The formation also contains greenish-colored marls and lignitic clays. The marls are usually decidedly fossiliferous. For the chemical composition of these clays see "Geology" of Clarke County.

The undifferentiated Claiborne consists of marls, sands and clays.

Jackson.—The Jackson formation is composed largely of clays, marls and sands. The clays usually contain crystals of selenite in considerable abundance. These clays contain, in places, the remains of a large, extinct, sea-animal, called the Zeuglodon. The sands of the Jackson are interbedded with beds of lignite or lignitic clays. The outcrops of the Jackson and the overlying Vicksburg form what is known as the "Central Prairie" belt of the State. The area of outcrop of the Jackson is broader than that of the Lisbon, which lies to the north.

Vicksburg.—The Vicksburg formation forms a narrow belt of outcrop on the southern margin of the Jackson outcrop. It consists of layers of compact limestone intercalated and interstratified with beds of marl and clay. The limestone and the marl are usually fossiliferous.

Grand Gulf (*including Pascagoula*).—The Grand Gulf forms the bed-rock for the greater part of southern Mississippi. The formation consists of gray, argillaceous sands and sandstones, white quartz-rocks, gravels and clays. The clays contain considerable organic

matter and are dark in color in some areas. In some exposures white chalk-like clays occur. The lower portion of the formation has been called the Pascagoula by Smith and Johnson of the Alabama Survey.

Lafayette.—The principal mantle-rock of southern Mississippi belongs to the Lafayette formation. The bed-rock is everywhere mantled with Lafayette, except where it has been removed by erosion. The formation consists of rounded quartz-pebbles, cherts, mottled clays and bright-red or orange sands, usually cross-bedded and lying unconformably upon the older formations.

Loess.—The loess is a mantle-rock formation, forming a narrow belt of territory along the Mississippi River and overlying the Lafayette. It exceeds one hundred feet in thickness in some places. It thins rapidly as the distance from the river increases. The loess is composed of a fine brown silt which contains irregular concretions of lime and numerous gastropod shells. It forms a large portion of the bluffs at Natchez and other points along the border of the Mississippi flood-plain.

Columbia.—Overlying the loess and the Lafayette is a brown or yellow loam which rests unconformably upon these two formations. The upper portion of the formation is generally a sandy loam or silt. The lower portion contains a higher per cent of clay substance. The thickness of the formation rarely exceeds ten or fifteen feet. The origin of these loams is doubtful. In many places they seem to be only a residual deposit formed on the Lafayette or the loess. The brown loam, which rests upon the surface of the latter, is very similar to it in many respects.

Port Hudson.—The Port Hudson formation consists of beds of sand, marls and clays. It may be of equivalent age with the Columbia, but representing a marine phase of that formation. The term Ponchartrain has been applied to a bed of clay which is probably of the same age. These clays are typically exposed around Lake Ponchartrain and extend along the Coast. The formation also extends up the Mississippi probably to near the Mississippi-Louisiana State line.

Recent Alluvium.—Alluvial silts, sands and clays are found in beds of considerable thickness along the flood-plains of the rivers, particularly is this true of the Mississippi, the Pearl and the Pascagoula.

Near the courses of the streams sands and sandy loams were

deposited by the swifter waters of the streams. In the inter-stream areas of the flood-plains, where the over-flow water had little velocity, clays and fine silts were deposited. The clays are generally waxy and of fine texture. In drying they shrink into cuboidal forms which have considerable space between each cube. In undrained areas they contain iron concretions called "buckshot."

CLAY-BEARING FORMATIONS.

The principal clay-bearing formations of southern Mississippi are the Jackson, the Grand Gulf, the Lafayette, the Columbia (yellow and brown loams) and the river alluvium.

Jackson Clays.—The clays of the Jackson formation are represented by numerous outcrops in the so-called "Central Prairie" belt of the State. The unweathered clays are usually bluish-green; where they are exposed for a period of time they change to a pale yellow. In some outcrops crystals of selenite are abundant. When sufficiently weathered and properly tempered the Jackson clays may be used successfully in the manufacture of brick by either the stiff-mud or the soft-mud process. The following table shows the average chemical composition of three samples of Jackson clay:

TABLE No. 1.

AVERAGE ANALYSIS OF JACKSON CLAYS.

Moisture (H_2O)	5.09
Volatile matter (CO_2, etc.)	6.72
Silicon dioxide (SiO_2)	60.25
Aluminum oxide (Al_2O_3)	12.65
Iron oxide (Fe_2O_3)	5.54
Calcium oxide (CaO)	6.69
Magnesium oxide (MgO)	.58
Sulphur trioxide (SO_3)	.40
Total	97.92

The average amount of clay substance in these samples is about 32 per cent. The amount of sand contained in the clay is nearly 41 per cent.

Grand Gulf Clays.—The unweathered clays of the Grand Gulf are usually gray, with a greenish cast. The weathered clays are red, yellow and mottled, though in some outcrops they are chalk-white. They are usually fine of grain and contain a large per cent of finely divided sand. Some of the Grand Gulf clays, after being thoroughly weathered, are adapted to the manufacture of brick by any of the processes of manufacture. However, on account of the minute size of the constituent

particles, the successful drying of some of the clays is attended with difficulties that are hard to overcome. Nearly all the clays of the formation dry slowly. In some localities the unweathered clays contain considerable quantities of iron pyrites. During the process of weathering the iron is either changed to the sulphate form and leached out, or it is oxidized. Gypsum, which is present in considerable abundance in some exposures, is also removed by the solvent action of water in weathering. The average chemical composition of four samples of Grand Gulf clay is given in the following table:

TABLE No. 2.

AVERAGE ANALYSIS OF GRAND GULF CLAYS.

Moisture (H_2O)	1.92
Volatile matter (CO_2, etc.)	3.31
Silicon dioxide (SiO_2)	74.48
Aluminum oxide (Al_2O_3)	10.11
Iron oxide (Fe_2O_3)	4.59
Calcium oxide (CaO)	.46
Magnesium oxide (MgO)	.40
Sulphur trioxide (SO_3)	2.18
Total	97.45

The average amount of clay substance in these clays is 25.57 per cent. The amount of sand contained is 59.02 per cent.

Lafayette Clays.—The Lafayette formation mantles the older formations in southern Mississippi. At the base of the formation in many places are beds of clays which are suitable for the manufacture of brick. These clays are usually plastic and easily molded. In some outcrops they contain too much gravel to be used with success in the manufacture of stiff-mud brick. The clay dries more rapidly around the pebbles which interfere with the wires in cutting. The clay is generally best handled by the soft-mud process. The analysis of a sandy type of Lafayette clay is given below:

TABLE No. 3.

ANALYSIS OF A SANDY, LAFAYETTE CLAY.

Moisture (H_2O)	2.23
Volatile matter (CO_2, etc.)	3.90
Silicon dioxide (SiO_2)	79.85
Aluminum oxide (Al_2O_3)	2.60
Iron oxide (Fe_2O_3)	3.75
Calcium oxide (CaO)	1.00
Magnesium oxide (MgO)	.15
Sulphur trioxide (SO_3)	.19
Total	93.97

The amount of clay substance in this sample is very small, only 6.58 per cent. About three-fourths of the contents of the clay are sand.

The bonding power of such a clay is necessarily low. Some of the clays from this formation contain a much higher per cent of clay substance.

Loess Clays.—Loess is used in a few places in the State in the manufacture of brick. Typical loess, especially that near the Mississippi River, is so finely comminuted and contains so much lime that bricks made from it are very easily broken. The loss of brick in some kilns ranges from one-third to nearly one-half. Where the material has been properly weathered a mixture of the loess and the overlying yellow loam makes a good, common brick. The weathered loess, which is found on the slopes of the bluffs, and that farther removed from the Mississippi River, is much better brick material than the unweathered loess.

A great improvement in the quality of the ware would result from the storing of the clay in covered sheds and allowing it to pass through a sweat before using. Storing the clay for a period of two months would greatly improve it. Still greater improvement would result from storing it for twelve months. The quality of the ware and the less amount of broken ware would pay the additional cost of handling the clay.

Columbia Clays.—Under the head of Columbia formation are included loams and clays which generally rest upon the surface of the Lafayette and the loess. "Brown loam" and "yellow loam" are terms which have also been applied to portions of the formation. The origin of the formation is in doubt, but it is very probably derived largely from the underlying formations. The Columbia clays are the principal sources of brick-material of southern Mississippi. They are used mainly in the manufacture of brick by the soft-mud process, though they are also used for stiff-mud and dry-pressed brick. The chemical composition of the Columbia clay may be seen in the following analysis, which is an average of four samples:

TABLE No. 4.

AVERAGE CHEMICAL COMPOSITION OF COLUMBIA CLAYS.

Moisture (H_2O)	3.02
Volatile matter (CO_2, etc.)	6.19
Silicon dioxide (SiO_2)	71.46
Aluminum oxide (Al_2O_3)	10.78
Iron oxide (Fe_2O_3)	5.49
Calcium oxide (CaO)	.86
Magnesium oxide (MgO)	.81
Sulphur trioxide (SO_3)	.53
Total	99.16

The amount of clay substance in the clay is 27.27 per cent. The clay contains 54.97 per cent of sand.

Recent Alluvial Clays.—The flood-plain areas of southern Mississippi contain alluvial clays which may be utilized successfully in the manufacture of brick. There are two general types of clays represented in these alluvial deposits. The first is a sandy clay which is generally deposited near the stream channels. The second is a more plastic type containing a higher percentage of clay and found in inter-stream areas. In the Yazoo basin the stiff clay is called "buckshot" clay. In color the first type is lighter than the second. In weight the reverse is true. An average chemical composition of two samples of these clays is given in the following table:

TABLE No. 5.

AVERAGE COMPOSITION OF ALLUVIAL CLAYS.

	Sandy Clay.	Buckshot Clay.
Moisture (H_2O)	2.68	6.26
Volatile matter (CO_2, etc.)	3.95	7.31
Silicon dioxide (SiO_2)	72.53	58.92
Aluminum oxide (Al_2O_3)	7.45	13.82
Iron oxide (Fe_2O_3)	6.04	8.74
Calcium oxide (CaO)	1.01	1.62
Magnesium oxide (MgO)	.69	.86
Sulphur trioxide (SO_3)	.39	1.74
Total	94.77	99.25

The amount of clay substance contained in the sandy clay is 18.84 per cent. In the second type it is 34.95 per cent. The amount of sand contained in the first type is 61.14 per cent; and in the second clay it is only 37.79 per cent. On account of the fineness of grain the "buckshot" clay presents difficulties in drying. The two clays may be more successfully utilized in making brick by mixing them.

BRICK CLAYS AND CLAY INDUSTRY OF SOUTHERN MISSISSIPPI BY COUNTIES.

ADAMS COUNTY.

GEOLOGY.

The bed-rock of Adams County consists of strata of Grand Gulf age. The Grand Gulf is composed of beds of clay, sand, sandstone and gravel. The surface of the bed-rock is concealed very largely by deposits of Lafayette, loess, Columbia and silt of the Mississippi.

The stratigraphy of the surficial formations may be studied best in the exposures along the bluffs of the Mississippi River. At Natchez, one mile north of the Yazoo and Mississippi Valley Railroad station, the following section is exposed in the river bank:

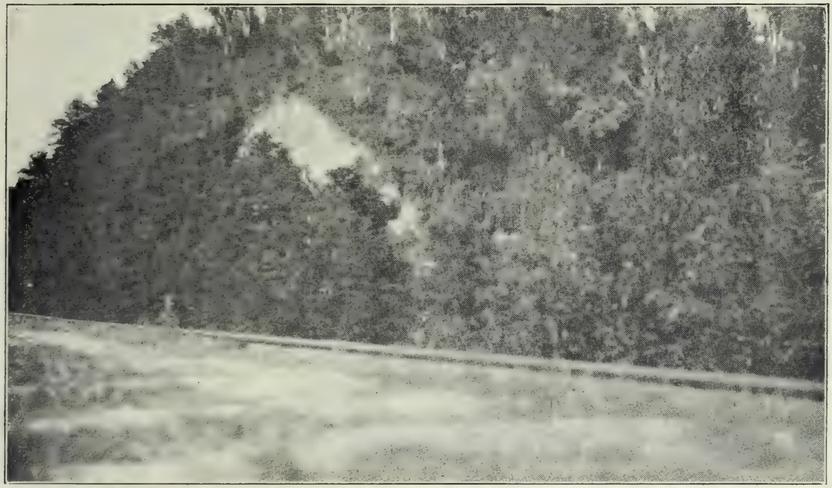
Section at Gravel Point North of Natchez.

		Feet.
5.	Loess, containing gastropod shells and lime concretions, capped in most places by a layer of brownish clay, grading into loam above, flour-like to the touch	40 to 50
4.	Reddish, sandy clay, coarse and gritty to the touch, apparently a residual product from a clayey sand	25 to 40
3.	Sands with gravel, tumultuously cross-bedded	100 to 150
2.	Coarse gravel and pebbles, yellow cherts predominate; some crystallines; many pebbles as large as 5 inches in one diameter, some cemented by limonite into pudding stone; layer exposed for 10 to 15 rods along river bank	8 to 10
1.	Greenish-gray clay, very plastic, exposed at water's edge; point of contact between this layer and the one above is about high-water mark or a little below	6 00

According to the views expressed by a majority of those who have made a study of the local stratigraphy at Natchez the following assignment would be the proper one for the various members of the above section: Stratum No. 1, belongs undoubtedly to the Grand Gulf, as that formation is now defined; No. 2 would be assigned to the Lafayette and No. 3 to the Natchez; No. 4 may be a residual deposit formed from the Natchez before the deposition of the loess (No. 5.)

Dr. T. C. Chamberlin, who made an examination of the geological conditions at Natchez, gave the name "Natchez" to a stratum of sands and gravels having a thickness of 200 feet. In speaking of the age of this formation Dr. Chamberlin says: (see Earth History, Volume III,

PLATE I.



A. LOESS BLUFF, NATCHEZ

B. GRAND GULF? GRAVEL AND CONGLOMERATE, NATCHEZ.

page 386, under the head of "Natchez Formation.") "At Natchez, Mississippi, there is a section of assorted material about 200 feet in thickness, which is chiefly made up of derivatives from the Lafayette formation, upon which it rests unconformably, but also contains crystalline pebbles and calcareous clays assignable to wash from the glacial regions, all other assignments seeming to be excluded by a special examination. A marked interval between its deposition and that of the overlying loess is indicated. As the sub-Aftonian and Aftonian deposits are the only older ones with which great gravel deposits are known to be associated, and as the Natchez deposit must be referred to an early Pleistocene stage because the great Mississippi trench, sixty miles more or less, in breadth, has been excavated since it was formed, reference to one of these two stages is more plausible than to a later one. This reference is strengthened by the fact that almost the whole formation—which was clearly a valley train leading back to the drift area—has been removed. . . . . ."

In the bluff on the south side of the boat-landing at Natchez, much the same stratigraphical conditions as those recorded above are revealed.

Section South of Boat Landing, Natchez.

		Feet.
6.	Loess	40 to 50
5.	Reddish, sandy clay	20 to 30
4.	Green clay with white concretions, stratified	5 to 10
3.	White to yellow, cross-bedded sands with some small gravel in lower portion	70 to 100
2.	Coarse gravel and sand	20 to 30
1.	Hard thin sandstones with concretions	5 to 10

According to the above interpretation of this Section No. 6 is loess; No. 1 is Grand Gulf; No. 2 is Lafayette; and all between No. 2 and No. 6 is Natchez.

In a bayou, which cuts back into the western portion of Natchez from the river-front, the stratigraphy of the upper portion of the above section is repeated in a large number of exposures. The stratigraphy of one of these outcrops is given below:

Section in Bayou, Natchez.

		Feet.
4.	Loess containing gastropod shells	20 to 40
3.	Red to yellow, coarse sand or sandy clay	10 to 25
2.	Greenish-gray, stratified clay	5 to 10
1.	Fine sand, cross-bedded	50 to 60

Following the view expressed above Nos. 1 and 2 belong to the Natchez; Nos. 3 and 4 belong to the loess.

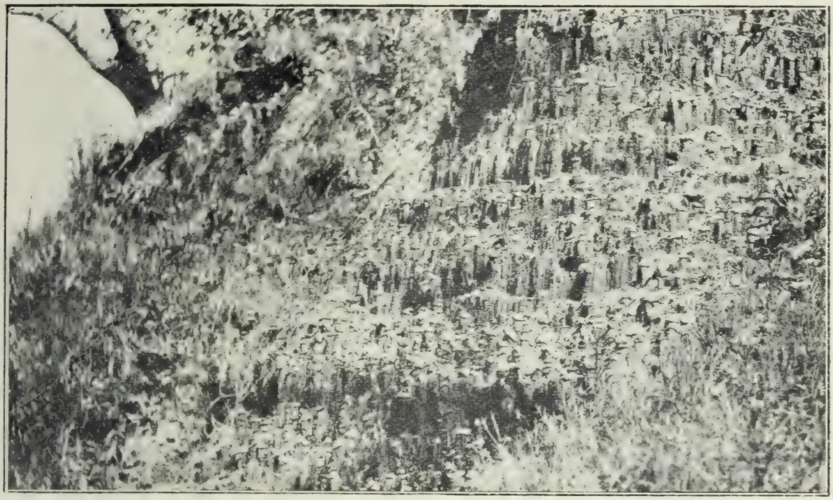
A question has been raised in the mind of the writer as to whether the sands and gravels referred to in the above sections as Lafayette and Natchez may not be referred properly to the Grand Gulf. In support of such an assignment the following facts may be cited:

1. *The relation of these beds to those below the water-level at Natchez.* The grayish-green clays at the water level, just below the coarse gravel (Section at Gravel Point) have been assigned to the Grand Gulf by all who have made a study of the local conditions. According to the record of the water-work's well, the mouth of which is located about fifty feet above the level of the water in the river, there are beds of sand and gravel below this bed of Grand Gulf clay. The stratigraphical conditions above and below the clay bed are, therefore, similar and beds of sand and gravel are not foreign to the Grand Gulf at Natchez.

2. *The presence of stratified clays overlying the sands and gravels.* Capping the Grand Gulf rocks at Stonington, in Jefferson County, is a layer of clay which contains white lime concretions. A clay containing similar concretions is found overlying many exposures of these sands at Natchez. These clays are greenish in color and stratified. The Natchez is not present, and such clays are not found at other points in connection with the Lafayette. They must be either Grand Gulf or loess.

3. *The thickness of the formation excludes a Lafayette assignment.* The thickness of the sand and gravel beds at Natchez is between 200 and 300 feet. After a careful study of hundreds of outcrops of Lafayette in the State of Mississippi, I am of the opinion that beds of Lafayette exceeding fifty feet in thickness are extremely rare. A similar conclusion has been reached by other members of the present survey, each following independent lines of investigation. In Water Supply and Irrigation Paper No. 159, United States Geological Survey, Crider and Johnson, in speaking of the thickness of the Lafayette, say: "It varies from a knife-edge to fifty feet or more in thickness. The latter thickness is very rare, and it is more often found to be less than ten feet." Dr. Calvin S. Brown, in Bulletin No. 3, Mississippi State Geological Survey, The Lignite of Mississippi, says: "The name Lafayette, then, as used in this paper, will apply only to that layer of

Plate II.



A. PINNACLES OF SAND PROTECTED BY PEBBLES, NATCHEZ.

B. PLANT OF THE NATCHEZ BRICK MANUFACTURING COMPANY, NATCHEZ

sand, or sand and gravel, usually from five to fifteen feet thick, rarely exceeding forty or fifty feet thick, which in Quarternary times has been deposited unconformably upon the older formations following the hills and slopes according to the conformation reached about the close of the Tertiary period."

These facts are presented as an argument against the assignment of the whole of the sands and gravels of these beds to the Lafayette. Of course these facts have no bearing upon the assignment of the beds to the Natchez or to the Lafayette and Natchez.

4. *The presence of sands and gravels in the Grand Gulf at other points in the State.*—A log obtained from a well located at Columbia shows one hundred and sixty-eight feet of sands and gravels.. This bed is, doubtless, of Grand Gulf origin, since the greenish-gray clays of the Grand Gulf are found within a few feet of the surface near Columbia and form numerous outcrops at higher elevations along the bluffs of Pearl River. Sands and gravels also occur in Grand Gulf strata at Hattiesburg, Maxie, Bond, Howiston, Lumberton and other places.

5. *The stratigraphy of the Mississippi bluffs.*—At Yazoo City the Jackson clays and marls form the main body of the bluffs. These hills rise to a height of 300 to 400 feet above the flood-plain of the river. The Lafayette does not exceed twenty-five feet in thickness and contains a few gravels. The Natchez is not present. The loess lies upon the Lafayette and caps the tops of the hills.

At Vicksburg the main body of the bluffs is composed of the Vicksburg formation. The Lafayette, which overlies the Vicksburg, does not exceed twenty or twenty-five feet in thickness.. It contains a few water-worn pebbles and resembles, in a general way, stratum No. 4, in the Gravel Point section at Natchez. The Lafayette at Vicksburg is overlain by a thick bed of loess.

At Grand Gulf all the rocks of the bluffs, except the loess, are referred to the Grand Gulf formation by Hilgard. The rocks of the Grand Gulf at this point consist of sands, sandstones and clays.

At Ft. Adams, below Natchez, the main body of the bluffs is composed of sands and sandstones, which are considered to be of Grand Gulf age. The Grand Gulf formation is concealed by beds of Lafayette and loess.

The main body of the bluffs, both above and below Natchez, in so far as the observations of the writer are concerned, is composed of

strata older than the Lafayette. This being true, if we assume that the main body of the bluffs at Natchez is composed of strata younger than the Grand Gulf, we must assume exceptional conditions at that point. We must assume that a deep trench was cut in the Grand Gulf at right angles to the present trend of the river; that this trench was cut to the present water-level of the river; and that in this trench were deposited Lafayette sands and gravels, followed by the sands and gravels of the Natchez. Do such exceptional conditions exist or does the main body of the bluffs at Natchez, like the bluffs above and below, belong to the Grand Gulf?

CLAYS AND CLAY INDUSTRY.*

The loess and the Columbia, brown loam phase, which is, probably, largely a residual product of the loess, are being used in Adams County in the manufacture of brick. Other clay-bearing formations are the Lafayette, the Grand Gulf and the recent alluvium of the Mississippi flood-plain.

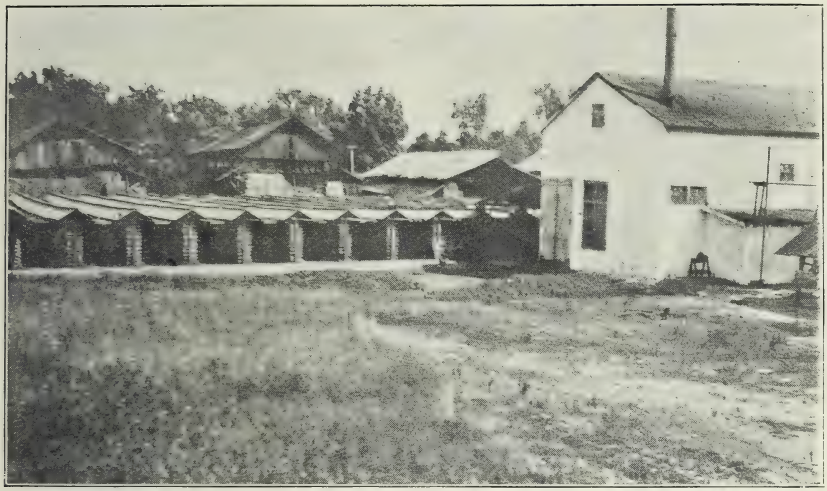
Natchez.—The Concord Brick Company of Natchez was organized in 1902. Three kinds of clay are used, a top loam, a middle, plastic clay and the non-plastic loess lying beneath. These are mixed together in the manufacture of brick by the soft-mud process. The bricks are molded in a steam-power machine. They are dried on pallets in open-air racks and are burned in up-draft kilns of the clamp type.

The plastic clay has a specific gravity of 1.97; has an air-shrinkage of 6 per cent, and requires 24 per cent of water to render it plastic. The clay slakes readily and speedily. The medium-burned briquets absorb from 8 to 12 per cent of water. The briquets lose about 5 per cent in weight in passing from an air-dried to a burned condition.

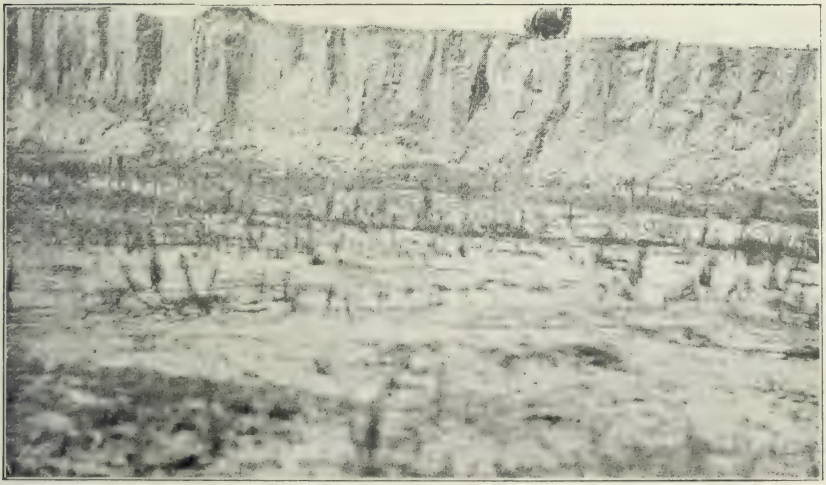
The Natchez Brick Manufacturing Company was established in 1897. The clay-pit exhibits about five feet of clay overlying the loess, but separated from it by about three feet of transitional material. One foot of the loess is mixed with the eight feet of overlying loam and clay in the manufacture of brick by the soft-mud process. The bricks are molded in a steam-power machine. The clay is first prepared in a dis-

*All briquets, the tests of which are recorded in the following pages, have been molded according to the method described on page 79 of Bulletin No. 2 of the Mississippi State Geological Survey. The burned briquets, the absorption tests of which are given, were all burned to a medium degree of hardness except as otherwise stated.

PLATE III



A. PLANT OF THE CONCORD BRICK MANUFACTURING COMPANY, NATCHEZ.



B. CLAY-PIT OF THE CONCORD BRICK MANUFACTURING COMPANY, NATCHEZ

integrator and pug mill. The bricks are placed on pallets and dried in sheds. They are then burned in clamp-kilns. The clay-pit is not far from the Concord Brick Company's pit, and the physical and chemical properties of the clays are very similar.

An analysis of a sample of gray loess is given below:

TABLE No. 6.

ANALYSIS OF LOESS, FROM NATCHEZ.

Insoluble matter	67.377
Peroxide of iron Alumina	5.920
Potash	.139
Soda	.104
Lime	11.934
Magnesia	2.084
Brown oxide of manganese	.171
Phosphoric acid	.138
Sulphuric acid	.002
Carbonic acid	8.976
Organic matter and water	3.087
Total	99.932

The alluvial clay-deposits of Adams County have not been used as yet in the manufacture of brick. The flood-plain areas of the streams afford two types of clays, a sandy type, which occurs near the present streams, and a more plastic, inter-stream type. By a proper mixture of these two clays, brick and drain tile of good quality may be manufactured.

AMITE COUNTY.

GEOLOGY.

Amite County lies within the area underlain by the Grand Gulf formation. The bed-rock is largely concealed by the more surficial deposits of Lafayette and brown loam or Columbia. The gray clays of the Grand Gulf out-crop in deep cuts, and in other places where the sands and gravels of the Lafayette and the silty loams of the Columbia have been removed by erosion.

CLAYS AND CLAY INDUSTRY.

The clays of Amite County, suitable for the manufacture of brick, belong to the surface formations. Bricks have been manufactured at Liberty, Gloster and Peoria.

Liberty.—The Liberty Brick Manufacturing Company uses yellow, surface clay in the manufacture of brick by the soft-mud process.

The clay is tempered in a ring-pit. The bricks are molded by hand and dried in racks. In the clay-pit about five feet of yellow clay rests upon a bed of sand and gravel of Lafayette age. The clay from the yellow layer is sandy in the upper portion, but increases in clay-content toward the bottom.

Gloster.—In 1907 a few kilns of bricks were manufactured at Gloster. The clay used was yellow surface clay. It was tempered in a circular pug-mill and molded by hand. The bricks were burned in up-draft scove kilns.

Peoria.—A few kilns of bricks have been manufactured at or near Peoria. The clay used is a surface clay of Columbia age. The bricks were manufactured by the hand process.

CLAIBORNE COUNTY.

GEOLOGY.

Claiborne County contains the type locality of the Grand Gulf formation. The typical outcrop of the formation is at Grand Gulf, on the Mississippi River. As described by Dr. E. W. Hilgard (Geology and Agriculture of Mississippi, p. 148), the stratigraphy of the outcrop is as follows:

Section of the Bluff at Grand Gulf, Claiborne County.

		Feet.
12.	Calcerous silt of the Bluff formation, forming the hilltops	60 to 70
11.	Grand Gulf sandstone in ledges 10 inches to 2 feet in thickness; stratification often discordant and curved	14
10.	Gray sandy material, sometimes soft sandstone, with an argillaceous cement alternating with harder ledges 6 to 10 inches thick of friable, whitish sandstone	15
9.	Solid, whitish sandstone, of good quality	2½
8.	Greenish-gray clay with white veins of carbonate of lime	2½
7.	Soft white sandstone	1
6.	Grayish-yellow pipe clay	½
5.	Dark-gray, brittle sandstone	1
4.	Gray semi-indurate, clayey sand	3
3.	Gray and yellowish sands and clays, semi-indurate, interstratified	17
2.	Semi-indurate, gray sand	3
1.	Greenish-gray clay, with veins of carbonate of lime	2

The Grand Gulf is concealed in all places by deposits of Lafayette, loess and Columbia, except where erosion has removed the latter formations.

About one-half mile north of Martin, on the Yazoo and Mississippi Valley Railroad, the following section is exposed in a cut:

Section Near Martin.	Feet.
4. Brown loam	3
3. Gravel and sandy loam	2
2. Red, sandy clay	8
1. White quartz rock	10

No. 1 is an almost pure, crystalline quartz-rock, belonging to the Grand Gulf formation. Nos. 2 and 3 are of Lafayette age, and No. 4 belongs to the Columbia.

In the southeastern part of this county, near Brandywine, are numerous outcrops of Grand Gulf clays, claystones and standstones. Some of the claystones weather, first, into parallelopipeds, then, by concoidal fracture, into lens-like bodies. In many places the surface deposits of Lafayette and Columbia loam are eroded into a "bad-land" type of topography. Some of the Grand Gulf claystones contain impressions of leaves. The chemical analyses of some of the clays, sandstones and claystones are found in the following table:

TABLE No. 7.

ANALYSES OF GRAND GULF CLAYS AND SANDSTONES.

	No. 3.	No. 4.	No. 7.	No. 8.
Moisture (H_2O)	3.59	1.09	00.74	2.36
Volatile matter (CO_2, etc.)	2.93	2.98	1.51	4.01
Silicon dioxide (SiO_2)	77.44	82.42	92.13	74.92
Aluminum oxide (Al_2O_3)	11.09	9.65	2.96	13.25
Iron oxide (Fe_2O_3)	4.17	2.40	1.61	2.96
Calcium oxide (CaO)	0.53	0.70	.54	.20
Magnesium oxide (MgO)	.31	.46	.42	.38
Sulphur trioxide (SO_3)	.05	.12	2.12	00.00
Total	100.11	99.62	99.96	100.20

No. 3 is a sandstone from near Brandywine; No. 4 is a very silicious clay from the same locality; No. 7 is a sandstone from near Clark, and No. 8 is a silicious clay from the same place.

CLAYS AND CLAY INDUSTRY.

The clay industry of Claiborne County has been developed only to a very limited extent. The clay-bearing formations are the Grand Gulf, the Lafayette and the Columbia.

Port Gibson.—The Port Gibson Brick and Tile Company was established in 1889. The old plant was burned and new machinery was installed in 1907. In the old plant the bricks were molded by the

stiff-mud process. They were dried in racks and burned in up-draft, clamp-kilns.

The clay slakes readily, is easily crushed and tempered. It is free from concretions and hard lumps which interfere with molding and cutting. The water required for plasticity is about 22 per cent. In air-drying the briquets shrink about 6 per cent. The burned briquets are red, and have an absorbtion of 8 to 10 per cent for medium hardness.

The thickness of the clay in the pit is eight feet with two feet or more of non-plastic, loess-like material underlying it. The clay is fairly uniform in quality throughout its entire thickness.

The flood-plain areas of Claiborne County contain clays which, with proper care in molding, drying and burning, will make good brick. The more plastic of these clays contain from 35 to 40 per cent of clay substance.

CLARKE COUNTY.

GEOLOGY.

The bed-rock formations of Clarke County include the Claiborne group, the Jackson formation and the Vicksburg formation. The northern part of the county is underlain by the Tallahatta buhrstone division of the Claiborne. The southern limit of this formation extends in a line through Enterprise to a point near where the 32° parallel crosses the State line. The Calcareous Claiborne, which borders the Tallahatta buhrstone on the south, forms the bed-rock of the central part of the county. The Jackson formation underlies the remainder of the county, with the exception of the southwestern corner, which is underlain by the Vicksburg formation. The surficial deposits of the county belong to the Lafayette and the Columbia. The Lafayette is represented by sands, clays and ironstones which attain their maximum thickness on the divides between the streams. The Columbia is usually very thin, thicknesses of over ten to fifteen feet are rare.

The Calcareous Claiborne consists of marls and clays. Below is given the composition of two samples of the Claiborne marl. The first sample is from Parker's Ferry, on Chickasawhay River, and the second sample is from Falling Creek.

TABLE No. 8.

ANALYSES OF CLAIBORNE MARLS, CLARKE COUNTY.

	No. 1.	No. 2.
Insoluble matter	66.347	65.540
Alumina	4.167	2.125
Lime	9.782	15.330
Potash	1.208	.375
Soda	.339	.246
Magnesia	1.442	.599
Brown oxide of manganese	.097	.076
Peroxide of iron	6.405	2.209
Phosphoric acid	.145	.086
Sulphuric acid	.397	.159
Carbonic acid	6.254	10.650
Organic matter and water	3.356	2.579
Total	99.939	99.974

The Jackson formation consists of clays, sands and marls. In many localities the clay contains crystals of selenite and the bones of the Zueglodon, an extinct whale-like animal. A sample of the gypsum-bearing clay from the Smith-farm at Barnett has the following composition:

TABLE No. 9.

ANALYSIS OF BARNETT CLAY.

	No. 83 (Old Series.)
Moisture (H_2O)	5.55
Volatile matter (CO_2)	13.80
Silicon dioxide (SiO_2)	38.75
Aluminum oxide (Al_2O_3)	22.83
Iron oxide (Fe_2O_3)	3.14
Calcium oxide (CaO)	14.25
Magnesium oxide (MgO)	1.01
Sulphur trioxide (SO_3)	Trace.
Total	99.33

The composition of three samples of marl from the Jackson formation of Clarke County is given below. No. 1 is from Smith's Spring; No. 2 is from Garland's Creek; and No. 3 is from Shubuta Ferry:

TABLE No. 10.

COMPOSITION OF JACKSON MARLS.

	No. 1.	No. 2.	No. 3.
Insoluble matter	72.783	45.881	52.289
Alumina	2.713	7.751	7.615
Lime	10.560	14.785	19.160
Potash	.639	1.117	.236
Soda	.096	.165	.100
Magnesia	.424	2.476	.355
Brown oxide of manganese	.094	.403	.368
Peroxide of iron	2.058	13.020	......
Phosphoric acid	.468	.327	.353
Sulphuric acid	.297	.566	.583
Carbonic acid	7.967	12.492	15.428
Organic matter and water	2.173	00.00	3.611
Total	100.272	99.883	100.090

The Vicksburg limestone occurs in ledges of considerable thicknesses, and, although massive in structure, it may be cut into blocks

with ease. It is quarried and used in portions of Clarke County for chimneys and for foundations of houses. A sample of the Vicksburg limestone from the western part of Clarke County has the following composition:

TABLE No. 11.

ANALYSIS OF VICKSBURG LIMESTONE, CLARKE COUNTY.

Moisture (H_2O)	1.00
Volatile matter (CO_2)	35.20
Silicon dioxide (SiO_2)	7.31
Iron oxide (Fe_2O_3)	4.00
Aluminum oxide (Al_2O_3)	13.66
Calcium oxide (CaO)	35.20
Magnesium oxide (MgO)	.29
Sulphur trioxide (SO_3)	2 78
Total	100.86

CLAYS AND CLAY INDUSTRY.

The clays of the surface formations are the only ones in Clarke County which have as yet been employed in the manufacture of brick. The Lafayette clays are predominantly red, though thin beds of white clay are occasionally encountered. The red clays are generally stiff, with a jointed structure. The proportion of clay substance to the sandy matter is somewhat variable, but, as a rule, the quantity of the latter is not adequate for making soft-mud brick. Two varieties of Columbia loam are represented: A white to gray loam, which usually contains iron concretions, especially in the lower portion, and a brown loam. The former may represent the undrained areas of the Columbia.

Quitman.—At Quitman Mr. C. S. Edmonson uses a mixture of red Lafayette clay and Columbia loam in the manufacture of brick by the soft-mud process. The clay-pit exhibits the following stratigraphic details:

Section of Quitman Clay-Pit.

		Feet.
4.	Soil	1
3.	Brown loam, white in places	2 to 3
2.	Lafayette, red clay	7
1.	Sand, Lafayette	1

The thickness of the sand in No. 1 is not revealed in the clay-pit, but the record of the artesian well located at the brick-yard gives the thickness of the Lafayette sand at this point.

Record of Artesian Well, Quitman.

		Thickness Feet.	Depth Feet.
1.	Soil, Columbia loam and Lafayette clay	10	10
2.	Sand, Lafayette	20	30
3.	Marl, Calcareous Claiborne	140	170

The bricks manufactured at the Edmonson plant are molded in a soft-mud machine, which has a daily capacity of 15,000 bricks, and is operated by horse-power. The bricks are placed on pallets in covered racks and dried. They are burned in up-draught clamp-kilns, the water-smoking and burning requiring ten to twelve days for completion.

The chemical composition of the Columbia clays used at the Edmonson plant is found in the following table. No. 129 is the brown clay; No. 130 is the gray clay:

TABLE No. 12.

ANALYSES OF QUITMAN CLAYS.

	No. 129.	No. 130.
Moisture (H_2O)	1.64	1.50
Volatile matter (CO_2, etc.)	3.75	3.42
Silicon dioxide (SiO_2)	81.54	78.77
Aluminum oxide (Al_2O_3)	2.47	9.27
Iron oxide (Fe_2O_3)	4.15	3.00
Calcium oxide (CaO)	3.22	1.25
Magnesium oxide (MgO)	0.20	0.11
Sulphur trioxide (SO_3)	0.13	0.25
Total	97.10	97.57

RATIONAL ANALYSES.

	No. 129.	No. 130.
Clay substance	6.25	23.45
Free silica	77.76	64.57
Fluxing impurities	7.70	4.61

The brown and the gray clay are mixed in the manufacture of brick and have about the same slaking speed. The amount of water required to render the mixture plastic adds 20 per cent to the weight of the clay. The amount of shrinkage which the clay undergoes in air-drying is 8 per cent. The average tensile strength per square inch of the brown clay briquets is 60 pounds.

COPIAH COUNTY.

GEOLOGY.

Copiah County lies within the area underlain by the Grand Gulf. The rocks of this group consist of clays, gravels, sands and sandstones. The mantle of Lafayette and Columbia, common to the Grand Gulf area, is present in this county also. The shallow wells which pierce this mantle, and usually obtain their water from its base, vary in depth from twenty to sixty feet. The stratigraphy of the mantle-rock is revealed in a railroad cut south of the brick-plant at Hazlehurst.

Lafayette-Columbia Section at Hazlehurst.

		Feet.
4.	Soil	1
3.	Brown-colored loam	4 to 5
2.	Brown sand, containing gravel	2 to 3
1.	Pink sand, containing gravel	10 to 15

Nos. 1 and 2 are Lafayette and No. 3 is Columbia.

CLAYS AND CLAY INDUSTRY.

Crystal Springs.—At Crystal Springs the Taylor-Thomas Brick Manufacturing Company uses the surface-loam clay (Columbia) in the manufacture of brick. The record of the well at the brick-plant shows the following local stratigraphy:

Record of Well at Taylor-Thomas Brick Plant, Crystal Springs.

		Thickness. Feet.	Depth. Feet.
1.	Clay	12	12
2.	Red sand and sandstone	30	42
3.	Red and white sand and gravel	30	72
4.	Clay	3	75
5.	Water-bearing sand and gravel	5	80

The clay from No. 1 is used in the manufacture of brick by the Taylor-Thomas Company. The clay is pulverized in a disintegrator and tempered in a pug-mill. It is then molded in a stiff-mud machine of the end-cut, auger-type. The bricks are burned in up-draft kilns, after being dried in sheds.

Hazlehurst.—The Hazlehurst Brick Company uses the brownish-yellow clay of the Columbia in the manufacture of brick. The clay-pit contains about six feet of clay, which rests upon the orange-colored sands of the Lafayette formation. These sands have a thickness of forty to fifty feet in the gulches and wells about Hazlehurst.

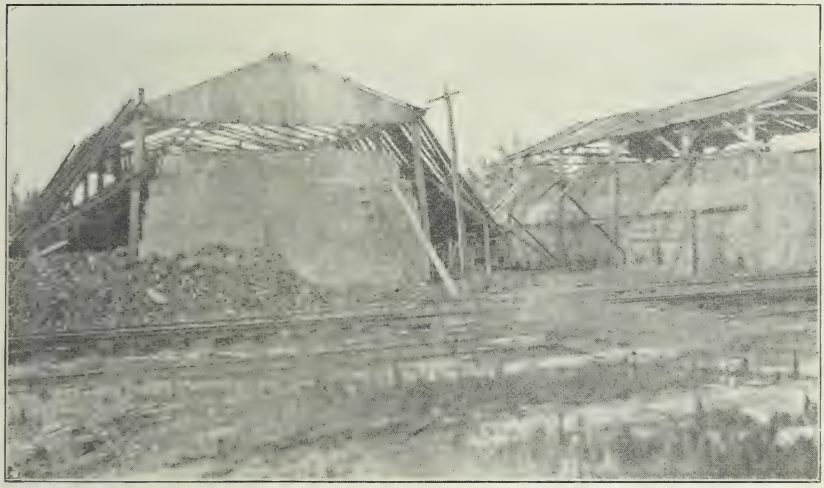
The clay used by this company is transported from the pit to the machine by the use of cable-cars, drum and hoist. The clay is then tempered in a pug-mill and molded in a stiff-mud, end-cut machine. The bricks are stacked in sheds to dry and are burned in clamp-kilns.

COVINGTON COUNTY.

GEOLOGY.

The strata underlying the surface deposits of Covington County are of Grand Gulf age. The rocks of the Grand Gulf consist of clays, sandstones and gravels. The bed-rock is largely concealed by the orange-colored sands of the Lafayette and the yellowish loam of the Columbia.

Plate IV.



A. KILNS OF THE MT. OLIVE BRICK MANUFACTURING COMPANY, MT. OLIVE.

B. CLAY-PIT OF THE MT. OLIVE BRICK MANUFACTURING COMPANY, MT. OLIVE.

CLAYS AND CLAY INDUSTRY.

The Lafayette and the Columbia formations contain suitable material for the manufacture of brick. The sandy clays of the Lafayette are suitable for the manufacture of soft-mud brick; the more plastic, Columbia clays, and the residual clay of the Grand Gulf may be used in other processes.

Mount Olive.—At Mount Olive a yellow clay and loam (Columbia) are used in the manufacture of brick by the Mount Olive Brick Manufacturing Company. The following section exhibits the different layers which occur in the clay-pit:

Section of Clay Pit, Mt. Olive.	Feet.
4. Soil, sandy	1
3. Yellow clay (Columbia)	6 to 10
2. Red sandstone (Lafayette)	1 to 2
1. White, sandy clay (Grand Gulf)	3

The surface of No. 2 is very irregular there being a decided unconformity between this layer and the upper one. The clay from No. 3 is used in the manufacture of brick. The clay is transported from the pit to the plant by means of cars attached by cable to a drum and hoist. It is crushed in a disintegrator and tempered in a horizontal pug-mill, and is then molded in a stiff-mud machine of the auger-type. The bar of clay is separated into bricks by an end-cut table. Open sheds and a steam-dryer are used to dry the bricks. The bricks are burned in rectangular, up-draft kilns of the clamp-type.

The analysis of a sample of the unburned clay from Mount Olive is given in the following table:

TABLE No. 13.

ANALYSIS OF MT. OLIVE CLAY.

	No. 127.
Moisture (H_2O)	3.17
Volatile matter (CO_2, etc.)	5.81
Silicon dioxide (SiO_2)	71.25
Aluminum oxide (Al_2O_3)	11.17
Iron oxide (Fe_2O_3)	5.90
Calcium oxide (CaO)	0.47
Magnesium oxide (MgO)	0.38
Sulphur trioxide (SO_3)	1.98
Total	100.13

RATIONAL ANALYSIS.

Clay substance	28.26
Free silica	54.16
Fluxing impurities	8.73

FORREST COUNTY.

GEOLOGY.

The bed-rock formation of Forrest County is the Grand Gulf. The rocks of the formation are clays, sands and gravels. An idea of the character of the formation may be gathered from the record of an artesian well at Hattiesburg.

Log of an Artesian Well, Hattiesburg.

	Thickness. Feet.	Depth. Feet.
Pinkish clay	100	100
Water-bearing sand	30	130
Greenish clay	150	280
Water-bearing sand and gravel	20	300

In a deeper well the greenish clay occurred at a depth of 600 feet. Exposures of Grand Gulf are to be seen along the courses of Leaf River and its tributaries. The surficial formations of the county are of Lafayette and Columbia age.

CLAYS AND CLAY INDUSTRY.

The Columbia clays are used in Forrest County in the manufacture of brick. These clays are not generally of very great thickness. In undrained or poorly drained areas they contain considerable "buck-shot" or iron concretions. In some places they rest directly upon the residual clays of the Grand Gulf, and in other places upon the sands and gravels of the Lafayette. The color of the clay is either gray or yellow and usually sandy in composition.

Hattiesburg.—At Hattiesburg bricks are manufactured by Mr. T. P. Crymes, who established his plant in 1902. The bricks are molded in a soft-mud, steam-power machine; dried in a steam dryer, and burned in up-draft, clamp-kilns. In the clay-pit a bed of yellow and gray clay, about three feet thick rests upon a plastic clay, which may be either Lafayette or Grand Gulf. The latter is too plastic to be used alone in the soft-mud process.

The Riverside Brick Company of Hattiesburg was established in 1901. The clay is prepared by crushing in a disintegrator and tempering in a pug-mill. The bricks are then molded in a soft-mud machine operated by steam-power. After being dried in sheds they are burned in clamp-kilns.

PLATE V.

PLANT OF THE CRYMES BRICK MANUFACTURING COMPANY, HATTIESBURG.

A gray clay mixed with a yellow loam and a sand are used in making brick. The composition of a sample of the yellow loam is given below:

TABLE No. 14.

ANALYSIS OF HATTIESBURG YELLOW LOAM.

	No. 123.
Moisture (H_2O)	1.27
Volatile matter (CO_2, etc.)	2.82
Silicon dioxide (SiO_2)	85.49
Aluminum oxide (Al_2O_3)	1.65
Iron oxide (Fe_2O_3)	2.52
Calcium oxide (CaO)	0.67
Magnesium oxide (MgO)	0.18
Sulphur trioxide (SO_3)	0.10
Total	94.70

RATIONAL ANALYSIS.

Clay substance	4.17
Free silica	82.97
Fluxing impurities	3.47

The following is an analysis of the gray clay:

TABLE No. 15.

ANALYSIS OF HATTIESBURG GRAY CLAY.

	No. 128.
Moisture (H_2O)	1.34
Volatile matter (CO_2, etc.)	2.84
Silicon dioxide (SiO_2)	87.45
Aluminum oxide (Al_2O_3)	1.87
Iron oxide (Fe_2O_3)	2.57
Calcium oxide (CaO)	2.50
Magnesium oxide (MgO)	0.13
Sulphur trioxide (SO_3)	0.37
Total	99.07

RATIONAL ANALYSIS.

Clay substance	4.73
Free silica	84.59
Fluxing impurities	5.57

It will be seen from the above analyses that these two materials have a low per cent of clay substance. When properly burned the bricks present the qualities of a good vitrified brick. For the manufacture of a stiff-mud brick different proportions of these clays would be necessary.

Maxie.—At Maxie a reddish clay belonging to the Lafayette overlies the siliceous Grand Gulf clays. This red clay contains a large amount of coarse sand. The thickness of the outcrop is about ten feet. A sample of the clay has the following composition:

TABLE No. 16.

ANALYSIS OF MAXIE CLAY.

	No. 135.
Moisture (H_2O)	2.23
Volatile matter (CO_2, etc.)	3.90
Silicon dioxide (SiO_2)	79.85
Aluminum oxide (Al_2O_3)	2.60
Iron oxide (Fe_2O_3)	3.75
Calcium oxide (CaO)	1.00
Magnesium oxide (MgO)	0.15
Sulphur trioxide (SO_3)	0.19
Total	93.67

RATIONAL ANALYSIS.

Clay substance	6.58
Free silica	75.88
Fluxing impurities	5.09

This clay is not sufficiently plastic to be used alone in the manufacture of stiff-mud brick. However, it could be employed with success in the manufacture of soft-mud brick. In some places a residual clay, which occurs at the base of the Lafayette, may be used in the manufacture of brick. However, care must be exercised in drying such clays in order to prevent cracking.

FRANKLIN COUNTY.

GEOLOGY.

Franklin County is underlain by Grand Gulf strata consisting of sandstones, clays and sands. The surface deposits are of Lafayette and Columbia age. The white sandstones of the Grand Gulf in Franklin County out-crop in a ridge along the principal divide, which forms what is termed the "Devil's Backbone." Below is given the composition of a sample of gray, Grand Gulf clay from Cassidy's Bluff, on Homochitto River:

TABLE No. 17.

ANALYSIS OF GRAND GULF CLAY, CASSIDY'S BLUFF.

Insoluble matter	49.475
Alumina	12.587
Lime	13.190
Potash	1.242
Soda	.152
Magnesia	1.829
Brown oxide of manganese	.266
Peroxide of iron	5.538
Phosphoric acid	.132
Sulphuric acid	.033
Carbonic acid	9.555
Organic matter and water	5.876
Ttoal	99.875

CLAYS AND CLAY INDUSTRY.

The clay industry in this county has been only slightly developed. Surface clays, from which a good grade of brick may be manufactured, are abundant, and for that reason, the future of the industry is bright. The best clays for brick are the surface, residual loess and the Columbia loam.

Meadville.—The Meadville Brick Manufacturing Company was established in 1907. The bricks are manufactured by the stiff-mud process. The clay used is a surface clay of Columbia age.

The analysis of the Grand Gulf clay from Cassidy's Bluff, referred to under the head of Geology, exhibits nearly 32 per cent of clay substance. It has the proper plasticity for a good, stiff-mud or dry-pressed brick. The per cent of lime which it contains would be detrimental unless uniformly distributed in the clay. On account of the fineness of grain of the sand contained in the clay, the ware must be dried with great care in order to prevent cracking.

GREENE COUNTY.

GEOLOGY.

Greene County is one of the counties which lies within the area of the Grand Gulf outcrop. The formation consists for the most part of sands and of greenish-gray clays. In the Leakesville well 350 feet of these clays were penterated. The record of the well is given below:

Record of the Leakesville Public Well.

		Thickness. Feet.	Depth. Feet.
1.	Sandy, yellow clay	6	6
2.	Bluish, pipe clay	10	16
3.	Water-bearing sand	24	40
4.	Greenish-gray clay	350	390
5.	Water-bearing sand	10	400
6.	Bluish clay	50	450
7.	Water-bearing sand	30	480

The Grand Gulf clays are exposed in the banks of Chickasawhay River at Leakesville. They overlie a stratum of white sand. The water flowing over the surface of the clays leaves a yellow, iron, rust-like incrustation or coloration. This iron-deposit is, doubtless, produced by the oxidation of the iron pyrites contained in the clay.

The bed-rock of Greene County is largely concealed by beds of Lafayette and Columbia. A range of high hills in the southeastern part of the county is capped by Lafayette sands and clays. Numerous springs are found along the line of contact between the sands and the underlying clays.

CLAYS AND CLAY INDUSTRY.

The clays of Greene County belong to the Grand Gulf, the Lafayette and the Columbia formations. The clays of the Lafayette are generally red in the upper part and mottled near the base of the formation. At many points the Columbia loam rests directly upon the surface of this clay, no sand or gravel being present. The clays from the Lafayette and the Columbia are used in Greene County in the manufacture of brick.

Leakesville.—The Leakesville Brick Manufacturing Company was organized in 1906. The bricks are molded in a stiff-mud machine of the vertical type. They are dried in open sheds and burned in scove kilns. The clay-pit exhibits three kinds of clay, as shown in the following section.

Section of Clay-Pit, Leakesville.	Feet.
4. Sandy soil	1
3. Sandy loam, yellow	3
2. Gray and red-mottled, plastic clay	3
1. Greenish-gray clay	4

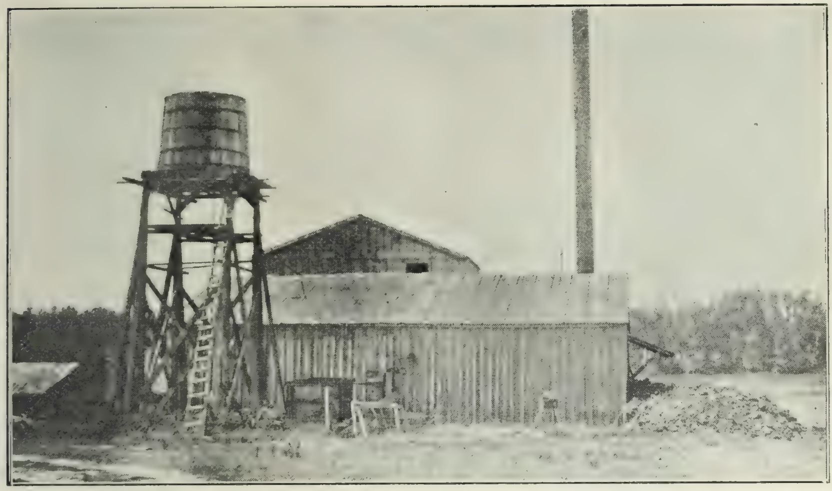
In the analyses given below No. 122 is a sample taken from layer No 1; No. 124 is a sample of the mixture of layers Nos. 2 and 3, used in the manufacture of brick.

TABLE No. 18.

ANALYSES OF LEAKESVILLE CLAYS.

	No. 122.	No. 124.
Moisture (H_2O)	2.86	1.54
Volatile matter (CO_2, etc.)	3.94	2.95
Silicon dioxide (SiO_2)	62.31	84.76
Aluminum oxide (Al_2O_3)	5.52	2.62
Iron oxide (Fe_2O_3)	17.48	6.98
Calcium oxide (CaO)	7.50	0.57
Magnesium oxide (MgO)	0.41	0.02
Sulphur trioxide (SO_3)	0.34	0.25
Total	100.36	99.69

Plate VI



A POWER-PLANT OF THE SUMMIT BRICK MANUFACTURING COMPANY, SUMMIT.

B. CLAY-PIT OF THE LEAKESVILLE BRICK MANUFACTURING COMPANY, LEAKESVILLE

TABLE No. 18—Continued.

RATIONAL ANALYSES.

Clay substance	13.96	6.62
Free silica	53.87	80.76
Fluxing impurities	25.73	7.82

The yellow, sandy loam slakes readily, but does not contain much clay substance. The mottled clay does not contain as much sand as the yellow clay and the particles adhere more firmly. The gray clay, at the bottom, contains the highest per cent of clay substance. It also contains a high per cent of fluxing impurities, especially iron. The iron in the form of an oxide originates from the decomposition of iron pyrites contained in the clay.

When properly treated the clays from layers 2 and 3 will make a fair quality of brick.

HANCOCK COUNTY.

GEOLOGY.

The rocks of the Grand Gulf and the Port Hudson underlie the mantle-rock of this county. The mantle-rock consists of beds of Lafayette sands and loams, of Columbia age, as well as residual clays and sands from the older formations.

CLAYS AND CLAY INDUSTRY.

The clay industry of Hancock County has been but little developed. A surface clay is being used in the manufacture of brick at only one point.

Bay St. Louis.—In 1902 Mr. W. T. Moon located a brick plant about three miles north of Bay St. Louis. The clay used is a mottled sandy clay from a surface deposit. The stratigraphy of the clay-pit is given below.

Section of the Moon Clay-Pit, Bay St. Louis.	Feet.
4. Soil, sandy	1
3. Sandy loam	3
2. Red and blue sandy clay	3
1. Sand	1

Layers 2 and 3 are used in the manufacture of brick. The bricks are molded in a steam-power, soft-mud machine and burned in up-draft kilns, after being dried in sheds.

The sandy loam slakes readily and does not contain a high per cent of clay substance. Layer No. 2 is a more plastic clay, which does not

slake as readily as the sandy loam. The amount of fluxing impurities is not excessive, but the clay contains enough iron to give a red color to the burned product.

HARRISON COUNTY.

GEOLOGY.

The principal bed-rock formation of Harrison County is the Grand Gulf. The sub-surface of the coastal area is composed of white sands and greenish marls which are younger than the Grand Gulf. These sediments were referred to the Port Hudson epoch by Dr. Hilgard. The white sands were named the Biloxi sands by Mr. L. C. Johnson. The term Ponchartrain has been applied to a group of coastal clays typically developed near Lake Ponchartrain and represented in Harrison County. The mantle-rock in the northern part of the county consists of beds of sands and gravels, and the residual clays and sands of the Grand Gulf.

CLAYS AND CLAY INDUSTRY.

The clays of Harrison County, which are being used in the manufacture of brick, are surface clays, probably of Columbia age.

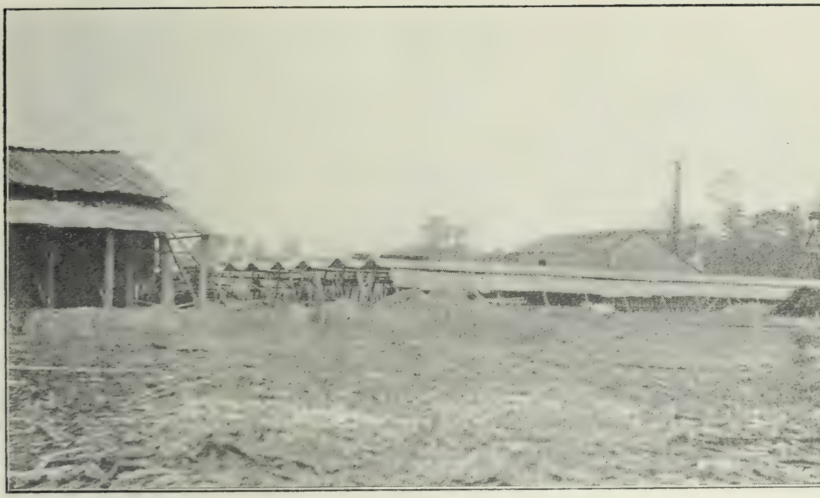
Landon.—The Landon Brick and Tile Company was established in 1902. The clay is brought from the pit in cars by the aid of drum and hoist. It is tempered in a pug-mill and molded in a stiff-mud machine of the horizontal type. A side-cutting table is used. The bricks are stacked in sheds for drying, and burned in up-draft, clamp-kilns. The clay-pit contains the following layers:

Section of Landon Clay-Pit.

		Feet.
3.	Yellowish loam and sand	5
2.	Bluish or mottled clay	4
1.	Dark clay with shells	6

Clay No. 2 is mixed with a portion of sandy clay from No. 3 in the manufacture of brick. A mixture of one-third sand to two-thirds clay seems to give the best results. The sand decreases the shrinkage and insures more successful results in drying and burning. The composition of this mixture is given in No. 125, in the table below; No. 126 is from layer No. 2:

Plate VII



A. PLANT OF THE LANDON BRICK AND TILE COMPANY, LANDON.

B. CLAY-PIT OF THE LANDON BRICK AND TILE COMPANY, LANDON.

TABLE No. 19.

ANALYSES OF LANDON BRICK CLAYS.

	No. 125.	No. 126.
Moisture (H_2O)	2.28	2.01
Volatile matter (CO_2, etc.)	4.17	4.84
Silicon dioxide (SiO_2)	78.00	77.52
Aluminum oxide (Al_2O_3)	7.72	10.87
Iron oxide (Fe_2O_3)	5.05	3.80
Calcium oxide (CaO)	1.40	0.60
Magnesium oxide (MgO)	0.16	0.43
Sulphur trioxide (SO_3)	0.30	0.08
Total	99.08	100.15

RATIONAL ANALYSES.

	No. 125.	No. 126.
Clay substance	19.53	27.50
Free silica	66.19	60.79
Fluxing impurities	6.91	4.91

The amount of sand-dilution reduces the clay-content from 27.50 per cent in the untempered clay to 19.53 per cent in the mixture. The amount of free silica is increased by 5.40 per cent. There is also an increase in the amount of fluxing impurities from 4.91 per cent in the untempered clay to 6.91 per cent in the mixture.

Biloxi.—The Imperial Brick Company of Biloxi, established a plant on Back Bay in 1906 for the manufacture of brick. The clay is prepared by a granulator and disintegrator and tempered in a horizontal pug-mill. The bricks are molded in a stiff-mud end-cut machine. They are dried in sheds and burned in rectangular, up-draft kilns. The clay-pit contains the following layers:

Clay-Pit of the Imperial Brick Company, Biloxi.	Feet.
3. Yellow clay	3
2. Sand and gravel	3
1. Greenish-colored clay	4

TABLE No. 20.

ANALYSES OF IMPERIAL BRICK COMPANY'S CLAYS, BILOXI.

	No. 133.	No. 134.
Moisture (H_2O)	2.52	6.71
Volatile matter (CO_2, etc.)	3.30	8.08
Silicon dioxide (SiO_2)	82.00	55.73
Aluminum oxide (Al_2O_3)	7.67	17.90
Iron oxide (Fe_2O_3)	3.00	8.50
Calcium oxide (CaO)	0.50	0.25
Magnesium oxide (MgO)	0.09	0.54
Sulphur trioxide (SO_3)	0.17	1.38
Total	99.25	99.09

RATIONAL ANALYSES.

	No. 133.	No. 134.
Clay substance	19.40	45.29
Free silica	70.27	28.34
Fluxing impurities	3.76	8.67

No. 133 is from layer No. 3; No. 134 is from layer No. 1.

The air-shrinkage of the surface clay is 9 per cent; its total shrinkage is 10 per cent. The amount of water required to render it plastic is 21 per cent. The raw clay has a tensile strength of 210 pounds; the burned briquets have a tensile strength of 315 pounds. When mixed with 10 per cent of coal the clay required 22 per cent of water to render it plastic; has an air-shrinkage of 8 per cent; a total shrinkage of 10 per cent; tensile strength, raw, 140 pounds, and burned 278 pounds. The clay mixed with 10 per cent of coal cinders requires 23 per cent of water to render it plastic; has an air-shrinkage of 8 per cent; a total shrinkage of 9 per cent; has a tensile strength, raw, of 230 pounds, and a tensile strength, burned, of 350 pounds.

The analyses of two samples of clay collected by Mr. A. F. Crider from outcrops at Biloxi are given in the following table:

TABLE No. 21.

ANALYSES OF BRICK CLAYS FROM BILOXI.

	No. 116.	No. 120.
Moisture (H_2O)	6.31	6.76
Volatile matter (CO_2, etc.)	5.20	6.49
Silicon dioxide (SiO_2)	68.80	58.80
Aluminum oxide (Al_2O_3)	12.55	14.52
Iron oxide (Fe_2O_3)	5.00	6.25
Calcium oxide (CaO)	1.92	0.92
Magnesium oxide (MgO)	0.27	0.60
Sulphur trioxide (SO_3)	0.08	0.91
Total	100.13	95.25

RATIONAL ANALYSES.

Clay substance	31.75	36.73
Free silica	49.60	36.59
Fluxing impurities	7.27	8.68

No. 116 is from the Watkins place and No. 120 is from the clay-pit of the Imperial Brick Company. These two clays contain a high percentage of clay substance, and, owing to their physical condition they are suitable for the manufacture of brick. They will each bear considerable sand-dilution. However, they appear to possess moderately weak bonding power, so that if the clay receives much dilution it will be necessary to burn the ware to the point of viscosity in order to insure the necessary strength. It is quite probable that saw dust mixed with the clay would give better results than sand, as sand reduces the bonding power.

Saucier.—At Saucier there in a stiff clay varying in color from red to blue and having the following composition:

Plate VIII.

A. KILNS OF THE IMPERIAL BRICK COMPANY, BILOXI.

B CLAY-PIT OF THE IMPERIAL BRICK COMPANY, BILOXI.

TABLE No. 22.

ANALYSIS OF SAUCIER CLAY.

	No. 119.
Moisture (H_2O)	4.60
Volatile matter (CO_2, etc.)	6.72
Silicon dioxide (SiO_2)	62.30
Aluminum oxide (Al_2O_3)	10.53
Iron oxide (Fe_2O_3)	10.35
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	0.45
Sulphur trioxide (SO_3)	0.20
Total	96.65

RATIONAL ANALYSIS.

Clay substance	26.64
Free silica	46.19
Fluxing impurities	12.50

This clay requires 25 per cent of water to render it plastic; has an air-shrinkage of 13 per cent; a total shrinkage of 15 per cent. In the raw state it has a tensile strength of 286 pounds; and a strength of 572 pounds, when burned. In table No. 23 the results of the dilution of Saucier clay, with various proportions of non-plastic substances, are given:

TABLE No. 23.

SAUCIER CLAY DILUTION.

Mixture.	Water required.	Shrinkage. Air.	Total.	Tensile Strength. Raw, lbs.	Burned, lbs.
Clay and ⅕ sand	22.13 %	7 %	10 %	170	154
Clay and ¼ sand	20.96 %	6 %	10 %	183	134
Clay and ⅓ sand	24.16 %	8 %	10 %	195	123
Clay and 10 % cinders	23.93 %	9 %	11 %	184	240
Clay and 10 % coal	25.89 %	9 %	12 %	173	163

The amount of clay substance in this clay is about that of the Landon clay, which requires a sand dilution of one-third. On account of the physical nature of the clay, dilution of some kind is necessary in order to facilitate drying. Judging from the above results the cinder-dilution is the best.

Ten-Mile.—At Ten-Mile in Harrison County, there is an outcrop of grayish-green clays belonging to the Grand Gulf. These clays weather to a yellow or brownish-red. A sample of the clay has the following composition:

TABLE No. 24.

ANALYSIS OF TEN-MILE CLAY.

	No. 136.
Moisture (H_2O)	5.32
Volatile matter (CO_2, etc.)	7.31
Silicon dioxide (SiO_2)	64.07
Aluminum oxide (Al_2O_3)	14.40
Iron oxide (Fe_2O_3)	6.27
Calcium oxide (CaO)	0.03
Magnesium oxide (MgO)	1.09
Sulphur trioxide (SO_3)	1.86
Total	100.35

TABLE No. 24—Continued.

RATIONAL ANALYSIS.

Clay substance	36.43
Free silica	42.04
Fluxing impurities	9.25

The per cent of clay substance in this clay is high as compared with the Landon mixture. Some form of dilution is essential to the successful working of this clay. The free-silica content is of very fine grain. The clay thus retains its moisture very tenaciously and some form of dilution is necessary to insure rapid and successful drying. Sandy loams are found in the surface deposits which may be utilized for this purpose.

Tchouticabouff River.—A sample of clay collected from Tchouticabouff River by Mr. A. F. Crider, has the following chemical properties:

TABLE No. 25.

ANALYSIS OF CLAY FROM TCHOUTICABOUFF RIVER.

	No. 118.
Moisture (H_2O)	1.46
Volatile matter (CO_2, etc.)	7.91
Silicon dioxide (SiO_2)	80.16
Aluminum oxide (Al_2O_3)	2.60
Iron oxide (Fe_2O_3)	1.35
Calcium oxide (CaO)	0.75
Magnesium Oxide (MgO)	0.45
Sulphur trioxide (SO_3)	1.11
Total	95.79

RATIONAL ANALYSIS.

Clay substance	6.57
Free silica	76.98
Fluxing impurities	3.66

The clay is dark, due, doubtless, to the presence of organic matter. It burns white. It contains only a small per cent of clay substance, and, therefore, lacks bonding power. The clay requires the addition of 20 per cent of water to render it plastic; has an air-shrinkage of 6 per cent, and a total shrinkage of 6 per cent; the tensile strength of the raw clay is 85 pounds; the tensile strength of the burned clay is 45 pounds.

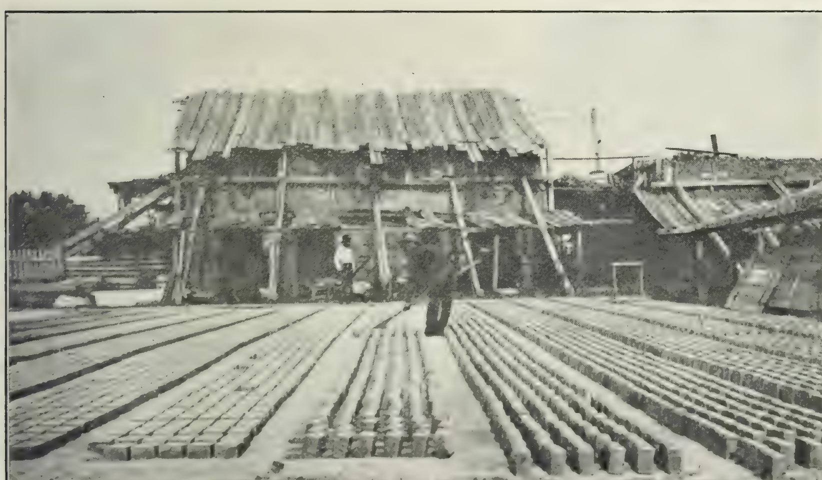
JACKSON COUNTY.

GEOLOGY.

Jackson is one of the counties of Mississippi bordering on the Gulf. The surface formations of the county are underlain by rocks belonging to the Grand Gulf and to the Port Hudson formations. The mantle rock consists of Lafayette sands and clays, Columbia loam and the

PLATE IX

A. SOFT-MUD, HORSE-POWER BRICK-MACHINE, MOSS POINT.



B. EDGING BRICK ON OPEN YARD, MOSS POINT.

residual material from the bed-rock formations. Alluvial clays, sands and loams have been deposited along the flood-plain of Pascagoula River, which constitutes the principal line of drainage for Jackson County.

CLAYS AND CLAY INDUSTRY.

The clays of Jackson County, which are being utilized in the manufacture of brick, belong to a surface deposit, probably of Columbia age. The clays are, as a general rule, yellow or blue and of a sandy nature.

Moss Point.—At Moss Point Mr. A. Blumer manufactures building brick by the soft-mud process. The bricks are molded in a soft-mud machine which is operated by horse-power. They are dried in open yards and sheds, and are burned in rectangular, up-draft kilns. The clay-pit contains a yellow sand or sandy clay overlying about three feet or more of yellow and blue clay. The two are mixed in order to produce the brick.

Orange Grove.—In 1906 The Orange Grove Brick and Tile Company erected a plant for the manufacture of brick by the dry-press method. The clay-pit contains a layer of gray or yellow clay resting upon a bed of sandy blue and yellow clay. The chemical composition of the yellow clay is shown in the following analysis:

TABLE No. 26.

ANALYSIS OF ORANGE GROVE CLAY.

	No. 121.
Moisture (H_2O)	3.15
Volatile matter (CO_2, etc.)	5.12
Silicon dioxide (SiO_2)	72.23
Aluminum oxide (Al_2O_3)	12.63
Iron oxide (Fe_2O_3)	5.87
Calcium oxide (CaO)	0.50
Magnesium oxide (MgO)	0.09
Sulphur trioxide (SO_3)	0.17
Total	99.76

RATIONAL ANALYSIS.

Clay substance	31.95
Free silica	52.91
Fluxing impurities	6.65

The per cent of clay substance is highest in the bottom layer. It is evident that one-half of the clay consists of sand. In crushing the clay there is a tendency for the more plastic portions to form pellets. These pellets are not always destroyed in molding. In order for the brick to have the proper tensile strength it is necessary, in burning, to raise the temperature of the clay to viscosity, at which point reunion of the particles takes place.

Ocean Springs.—A sample of clay collected by Mr. A. F. Crider from an out-crop at Ocean Springs, has the following composition:

TABLE No. 27.

ANALYSIS OF OCEAN SPRINGS CLAY.

	No. 117.
Moisture (H_2O)	5.16
Volatile matter (CO_2, etc.)	6.94
Silicon dioxide (SiO_2)	61.27
Aluminum oxide (Al_2O_3)	17.97
Iron oxide (Fe_2O_3)	3.88
Calcium oxide (CaO)	1.10
Magnesium oxide (MgO)	0.32
Sulphur trioxide (SO_3)	0.89
Total	97.53

RATIONAL ANALYSIS.

Clay substance	45.46
Free silica	38.77
Fluxing impurities	6.25

The clay contains a high per cent of clay substance, and, since the sand contained is in a finely divided state, considerable difficulty is experienced in drying it successfully. Further sand-dilution would result in a loss of bonding power. This loss could be met only by hard burning. The clay slakes slowly and requires 22 per cent of water to render it plastic. The tensile strength of the raw clay is 200 pounds per square inch. The burned briquets have a tensile strength of 450 pounds per square inch. Some of the clays cracked very badly at the point of incipient fusion.

JASPER COUNTY.

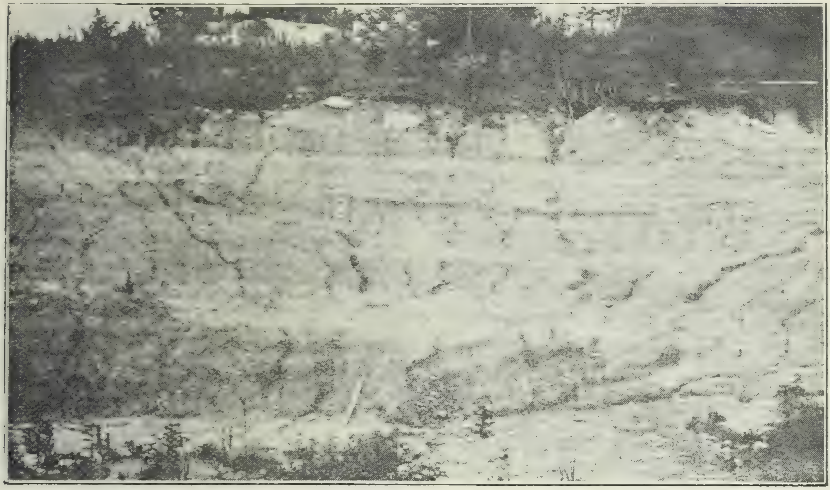
GEOLOGY.

The northeastern portion of Jasper County is underlain by the Calcareous Claiborne, consisting of marls and sands. The north-central portion of the county is underlain by Jackson clays, marls and sands. The south-central portion is underlain by the Vicksburg limestone, and the southwestern portion by the Grand Gulf clays. These bed-rock formations are mantled by deposits of sand, clays and loam belonging to the Lafayette and the Columbia.

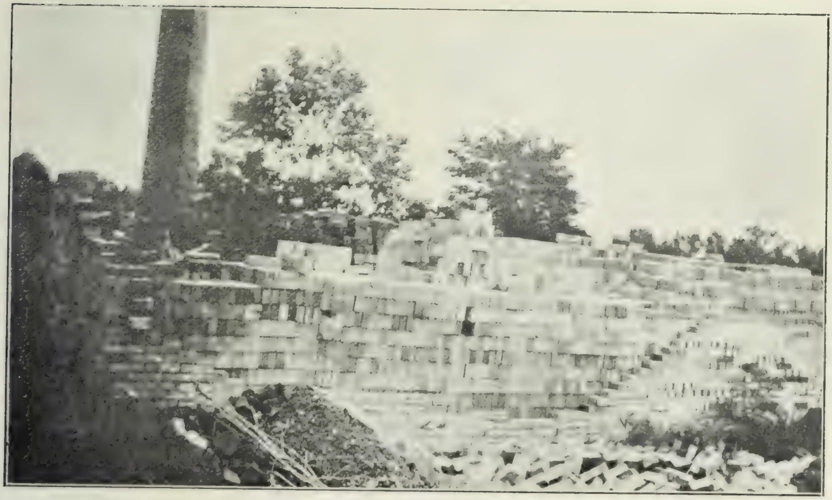
CLAYS AND CLAY INDUSTRY.

The clay industry has had very little development in Jasper County. Clays suitable for the manufacture of brick are to be found in the Lafayette and the Columbia formations, and the residual

PLATE X.



A. GRAND GULF WHITE CLAY, STONINGTON.



B. PRESSED BRICK MADE FROM GRAND GULF CLAY, STONINGTON.

clays of the older formations, particularly the Jackson and the Grand Gulf. These residual clays will, in most instances, require mixing with sand in order to insure successful drying.

JEFFERSON COUNTY.

GEOLOGY.

The bed-rock formations of Jefferson County belong to the Grand Gulf. The Grand Gulf rocks comprise sands, silicious clays, gravels and sandstones. The overlying beds of mantle-rock consist of sands and gravels of the Lafayette and the loams of the Columbia.

The stratigraphy of the mantle-rock and its relation to the underlying bed-rock, is revealed in the following section taken from a railroad cut at Fayette.

Section at Fayette.

		Feet.
4.	Brownish, yellow loam	6
3.	Gravel and loam	3
2.	Purple to red or green sticky clays	6
1.	Gray clay with thin layers of sandstone	5

Nos. 1 and 2 are of Grand Gulf age; No. 3 is Lafayette; and No. 4 Columbia. In a small draw west of the railroad station at Fayette another section is exposed as follows:

Section West of Station, Fayette.

		Feet.
4.	Brown loam	4
3.	Sandy clay and gravel	6
2.	Variegated clay	5
1.	White sandstone	4

CLAYS AND CLAY INDUSTRY.

The clays of Jefferson County, which have been used in the manufacture of brick, belong to the Columbia and to the Grand Gulf formations. The Columbia clays are brown or yellow, and may be used in any of the processes of brick manufacture, viz: Soft-mud, stiff-mud or dry-press. The Grand Gulf clays are gray or white, are plastic and contain considerable kaolin.

*Stonington.**—The Stonington Brick Company was organized in 1894, for the manufacture of pressed brick. The plant was recently

*Since this report went to press the Stonington plant has been destroyed by fire.

purchased by Mr. R. J. Searcy and is now operated and managed by him. The clay is prepared in a dry-pan and molded in a dry-press machine. The Columbia clay is used, which produces a red brick. The Grand Gulf clay produces a gray or white brick. By mixing these two clays it is possible to produce a speckled or mottled brick. The bricks are burned in a rectangular, down-draft kiln, in a beehive kiln and in a clamp-kiln. In one portion of the clay-pit the following layers of clay are exposed:

Section in Stonington Clay-Pit.	Feet.
4. Brown loam clay	10
3. Blue clay with white concretions	6
2. Sandstone in layers	8
1. Clay, white to gray	8 to 28

In another portion of the clay-pit are fifteen to twenty feet of a shale-like, white to bluish-gray clay. A sample of this clay has the following chemical composition:

TABLE No. 28.

ANALYSIS OF STONINGTON WHITE CLAY.

Moisture (H_2O)	1.24
Volatile matter (CO_2)	4.08
Silica (SiO_2)	78.17
Alumina (Al_2O_3)	13.23
Iron oxide (Fe_2O_3)	1.73
Lime (CaO)	.28
Magnesia (MgO)	.56
Sulphur trioxide (SO_3)	Trace.
Total	99.29

RATIONAL ANALYSIS.

Clay base	33.53
Free silica	57.87
Fluxing impurities	2.57

This clay may be classed as a stoneware clay. In the process of burning it becomes white or yellowish white. It is much more refractory than the brown clay and requires a much higher temperature to produce a hard brick. Its physical properties will be discussed more at length under a discussion of stoneware clays to comprise a future report.

JEFFERSON DAVIS COUNTY.

GEOLOGY.

The Grand Gulf forms the bed-rock of Jefferson Davis County. This formation consists of beds of sands, gravels and gray clays. The eroded sarface of the Grand Gulf is very largely concealed by clays,.

gravels and colored sands of the Lafayette and also by the loams of the Columbia. The greater part of the surface clays of the county lies along the divide between Leaf River and Pearl River. In some places the tributaries of these streams have cut through the surficial deposits and exposed the bed-rock.

CLAYS AND CLAY INDUSTRY.

The clay industry of Jefferson Davis County is in an undeveloped condition. Clays suitable for the manufacture of brick are to be found in the surficial formations. The Columbia contains, in some localities, particularly along the slopes of small valleys, beds of clay and loam which, under proper treatment, will be found to be suitable for the manufacture of brick. From the higher lands much of the Columbia has been removed by erosion, so that the soils are formed directly from the Lafayette sands. The Lafayette also contains beds of clays, some of which, with careful treatment, may be utilized in the manufacture of brick. The Grand Gulf clays, when they have been weathered thoroughly, afford good material for brick. The unweathered clays of this formation are not, as a rule, suitable for brick. The usefulness of the Grand Gulf clays is generally very much impaired by the difficulty experienced in drying them.

JONES COUNTY.

GEOLOGY.

The Grand Gulf formation constitutes the bed-rock of Jones County. The strata of the Grand Gulf consist of sands, clays and sandstones; the clays predominate. The town-well at Ellisville passed through the Grand Gulf strata into the underlying formations. The section of this well is given below. At least six hundred feet of the rocks belong to the Grand Gulf.

	Section of Ellisville Well.	Thickness. Feet.	Depth. Feet.
1.	Sand and gravel	80	80
2.	Green clay	280	360
3.	Sand	10	370
4.	Green clay	230	600
5.	Sand rock	12	612
6.	Greenish marl	288	900
7.	Shell rock	5	905
8.	Green marl	195	1,100
9.	Shells	5	1,105
10.	Green marl	295	1,400

The rocks of the Grand Gulf are generally covered with sands and gravels of the Lafayette and the Columbia loams. The bright red sands of the Lafayette are particularly prominent along the divide between Moselle and Ellisville. The Columbia deposits are very thin or entirely wanting on the highest lands where the soils are formed largely from the Lafayette.

CLAYS ANY CLAY INDUSTRY.

The clays of Jones County belong to the Columbia, the Lafayette and the Grand Gulf. The Grand Gulf clays in this county, have not been used with much success in the manufacture of brick. An attempt to make brick was made at Ellisville a few years ago, and while it was possible to mold the bricks, all attempts to dry them successfully failed.

Ellisville.—The local stratigraphy of the surface clays may be seen in the following section taken in a railroad cut north of the station.

Section at Ellisville.	Feet.
4. Soil, sandy	1
3. Yellow loam (Columbia)	3
2. Yellow sand with some gravel (Lafayette)	3
1. Clay, greenish-gray (Grand Gulf)	10

The chemical composition of a sample from No. 3 is given below: As will be seen from this analysis this layer of rock contains a very small amount of clay substance. In fact there is not enough clay content for the manufacture of even soft-mud brick. The only way in which it could be utilized would be by the addition of a more plastic clay. Such clays may be found in the residual deposits of the Grand Gulf.

TABLE No. 29.

ANALYSIS OF ELLISVILLE CLAY.

	No. 139.
Moisture (H_2O)	0.25
Volatile matter (CO_2, etc.)	1.57
Silicon dioxide (SiO_2)	91.73
Aluminum oxide (Al_2O_3)	0.37
Iron oxide (Fe_2O_3)	2.05
Calcium oxide (CaO)	1.67
Magnesium oxide (MgO)	0.57
Sulphur trioxide (SO_3)	0.13
Total	98.34

RATIONAL ANALYSIS.

Clay substance	.93
Free silica	91.16
Fluxing impurities	4.23

PLATE XI.

A. PLANT OF THE LAUREL BRICK AND TILE COMPANY, LAUREL.

B. LAFAYETTE OVERLYING GRAND GULF CLAY, ELLISVILLE.

The greenish-gray clay from No. 1 has the following chemical composition:

TABLE No. 30.

ANALYSIS OF ELLISVILLE CLAY.

	No. 138.
Moisture (H_2O)	.85
Volatile matter (CO_2, etc.)	2.64
Silicon dioxide (SiO_2)	81.97
Aluminum oxide (Al_2O_3)	2.95
Iron oxide (Fe_2O_3)	6.17
Calcium oxide	.92
Magnesium oxide (MgO)	.15
Sulphur trioxide (SO_3)	.21
Total	95.86

RATIONAL ANALYSIS.

Clay substance	7.46
Free silica	77.46
Fluxing impurities	7.45

This clay is also deficient in clay content. It contains a large per cent of silica in the form of a very finely-divided sand. The difficulties of molding the clay are not great; but the molded brick cannot be dried successfully. Because of the already small amount of clay substance further dilution by the addition of sand would destroy the bonding power of the clay.

Laurel.—The Laurel Brick and Tile Company was organized in 1900. In 1907 the location of the plant was changed and new machinery installed. The clay is tempered in a horizontal pug-mill. It is then molded in a stiff-mud machine, and the bricks separated by the use of an end-cutter. The bricks are dried in a steam-dryer and burned in up-draft, clamp-kilns.

The clay-pit contains a yellow, sandy, top clay; below this is a bluish-gray clay which rests upon sand, the sand in turn resting upon a greenish clay. A sample of the gray clay has the following composition:

TABLE No. 31.

ANALYSIS OF LAUREL GRAY CLAY.

	No. 75 O. S.
Moisture (H_2O)	1.22
Volatile matter (CO_2, etc.)	3.66
Silicon dioxide (SiO_2)	84.86
Aluminum oxide (Al_2O_3)	5.28
Iron oxide (Fe_2O_3)	3.96
Calcium oxide (CaO)	0.23
Magnesium oxide (MgO)	0.45
Sulphur trioxide (SO_3)	0.00
Total	99.66

RATIONAL ANALYSIS.

Clay substance	13.38
Free silica	78.76
Fluxing impurities	4.64

The clay requires 24 per cent of water to render it plastic. It has a specific gravity of 2.62. The average tensile strength of the air-dried briquets is 70 pounds per square inch. The air-shrinkage is 2 per cent. The color of the burned product is red.

LAMAR COUNTY.

GEOLOGY.

The bed-rock of Lamar County belongs to the Grand Gulf group. A large part of the surface of the bed-rock is concealed by a mantle of Lafayette and Columbia. The Lafayette is represented by orange-colored sands which contain lenticular bodies of clay, and in some localities quantities of water-worn gravels. The Columbia forms a thin mantle of loam which is sandy in the upper portions, but is of a clayey nature in the lower part. The Grand Gulf stratigraphy is revealed by the well-record of the Camp-Hinton Lumber Company at Lumberton.

General Section of Camp-Hinton Well, Lumberton.

	Thickness. Feet.	Depth. Feet.
1. Surface and sand clay	40	40
2. Water-bearing sand and gravel	5	45
3. White clay and fine sand	650	695
4. Blue and green clays	200	895
5. Blue clay and sand	505	1,400
6. Soft blue clay and sand	400	1,800

CLAYS AND CLAY INDUSTRY.

Lumberton.—At Lumberton the Lafayette mottled clays are being used by the Lumberton Brick Manufacturing Company in the manufacture of stiff-mud brick. For a number of years the Columbia loam was used in the manufacture of brick by the soft-mud process. The plant was established in 1895. Ten years later, 1905, a new company was organized and new machinery installed.

The surface clay rests on the greenish-gray Grand Gulf clays and is probably a residual product of that formation. The yellow, sandy deposit of the Columbia mantles the Lafayette clays. The clay-pit exhibits the following layers:

Clay-Pit of the Lumberton Brick Company, Lumberton.

	Feet.
3. Yellow loam (Columbia)	3 to 4
2. Mottled clay (Lafayette)	5 to 6
1. Greenish-gray clay (Grand Gulf)	5

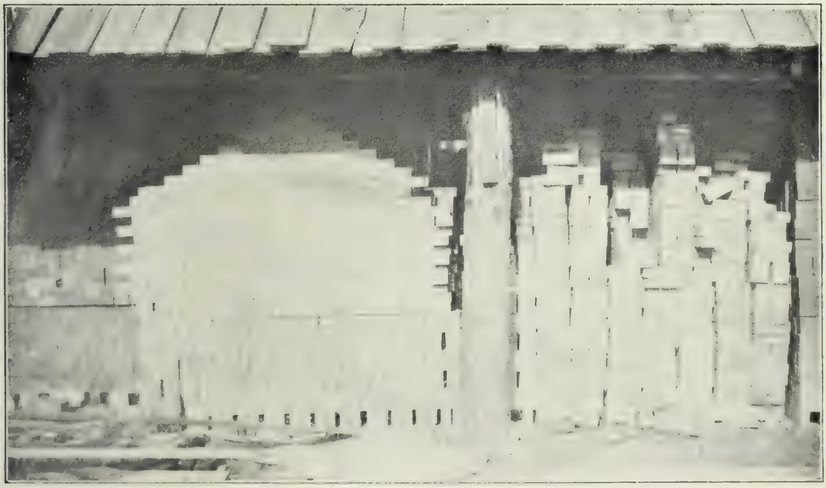
Plate XII.

A. PLANT OF THE LUMBERTON BRICK MANUFACTURING COMPANY, LUMBERTON.

B. STEAM-SHOVEL USED BY THE LUMBERTON BRICK MANUFACTURING COMPANY, LUMBERTON.

PLATE XIII.

A. BRICK PLANT OF A. SEAVEY AND SONS, BROOKHAVEN.



B. FLASHED BRICK MADE BY THE BROOKHAVEN PRESSED BRICK COMPANY, BROOKHAVEN.

The clay is mined by the use of a steam shovel, and transported to the clay machine by means of cars controlled by drum and hoist. It is tempered in a pug-mill and molded in a stiff-mud machine. The bricks are dried in open sheds and in steam-driers and burned in rectangular up-darft kilns of the clamp-type.

LAWRENCE COUNTY.

GEOLOGY.

Lawrence County lies within that portion of the State which is underlain by Grand Gulf strata. Clays, sands and gravels form the principal constituents of the group. The bed-rock is mantled by deposits of Lafayette, Columbia and the alluvium of Pearl River Valley.

CLAYS AND CLAY INDUSTRY.

There has been no development of the brick industry in Lawrence County. Suitable clays for brick manufacture may be found in the two surface formations. The Lafayette sandy clays may be used in the manufacture of brick by the soft-mud process. The more plastic clays of the Columbia and the residual clays of the Grand Gulf will be found suitable for the manufacture of stiff-mud brick. On account of the fineness of grain of the free silica in the Grand Gulf, great care in drying is necessary in order to prevent cracking.

LINCOLN COUNTY.

GEOLOGY.

Lincoln County lies within the area of the Grand Gulf group. The mantle-rock consists of beds of gravel, sands and loams belonging to the Lafayette and the Columbia. The Lafayette beds, as a rule, do not exceed fifty feet in thickness, while the Columbia is rarely ever half that thickness. Sands and gravels comprise the major part of the Lafayette, but there are also beds of red, mottled-red and white clays which lie normally at the base of the formation. On the high ridges between the streams the Columbia has been removed in many places and the soils are formed directly from the Lafayette.

CLAYS AND CLAY INDUSTRY.

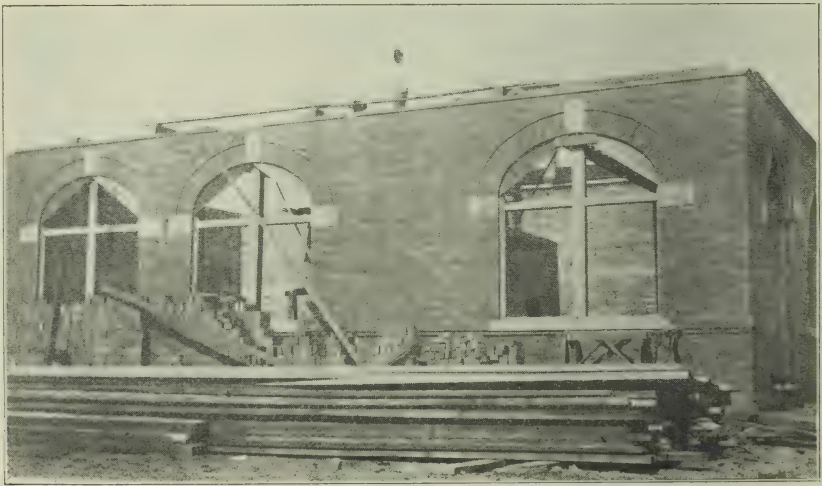
The clays which have thus far been used in Lincoln County for the manufacture of brick belong to the Columbia. Bricks have been manufactured at Brookhaven and Norfield.

Brookhaven.—Messrs. A. C. Seavey and Sons established a plant for the manufacture of brick at Brookhaven in the year 1892. The clay used is a yellowish-brown, surface clay. It is tempered in ring-pits and molded by hand. The bricks are dried in covered sheds by pallet and rack-system. Two kinds of up-draft kilns are used, round and rectangular.

The plant of the Brookhaven Pressed Brick Company was established in 1906. A surface clay of Columbia age is used in making brick. The clay is pulverized in a dry-pan and carried by a conveyor to a screen, after which it passes to an agitator and from the agitator to the press. The bricks are burned in rectangular, up-draft kilns.

Norfield.—At Norfield the surface-loam clay is used in the manufacture of brick by the Norfield Brick Manufacturing Company. The present plant was established in 1905. The clay is crushed by the use of a granulator and disintegrator, and tempered in a horizontal pug-mill. The clay is molded in a steam-power, soft-mud machine. The bricks are placed upon pallets and dried in sheds. The bricks are burned in rectangular up-draft kilns of the clamp variety.

PLATE XIV.



BUILDING CONSTRUCTED OF BROOKHAVEN PRESSED BRICK, SILVER CREEK.

MARION COUNTY.

GEOLOGY.

The bed-rock formations of Marion County are of Grand Gulf age. The surficial deposits of the county belong to the Lafayette, the Columbia and the alluvium of Pearl River Valley. The Grand Gulf strata consist of clays, claystones, sands and gravels. A gravel-layer, which probably belongs to the Grand Gulf, at Columbia, has a thickness of 168 feet. The following analyses are from samples of Grand Gulf clays; the first was taken from Burnett's Bluff and the second from Barnes' White Bluff:

TABLE No. 32.

ANALYSES OF GRAND GULF CLAYS.

	No. 1.	No. 2.
Insoluble matter	83.691	77.438
Alumina	8.347	6.449
Lime	.793	4.800
Potash	.827	.709
Soda	.268	.101
Magnesia	1.053	1.248
Brown oxide of manganese	.223	.316
Peroxide of iron	4.394	2.989
Phosphoric acid	.148	.111
Sulphuric acid	.022	Trace.
Carbonic acid	. 00	3.372
Organic matter and water	. 00	2.554
Total	99.766	100.087

CLAYS AND CLAY INDUSTRY.

Columbia.—The Columbia clays are being used in the manufacture of brick by the soft-mud process, at a point about one mile north of Columbia in Pearl River Valley.

PERRY COUNTY.

GEOLOGY.

The bed-rocks of Perry County belong to the Grand Gulf group. These rocks outcrop along the courses of the streams. They consist of greenish-colored clays, with an alum-like taste, and of white sands. The orange-colored sands of the Lafayette and the yellow loams of the Columbia constitute the principal surficial deposits. The alluvium of the river valleys is composed largely of the worked-over materials of these two formations.

CLAYS AND CLAY INDUSTRY.

The clay-bearing formations of the county are the Grand Gulf, the Lafayette and the Columbia. The clay industry has received very little attention as yet. Brick clays may be found in the Lafayette and the Columbia formations.

Out-crops of Grand Gulf clays are exposed along the courses of the streams, and in some places in railroad cuts. Exposures of the latter type are to be found near Beaumont. These clays are greenish-gray in fresh exposures, but weather to red or yellow in residual deposits. This condition is brought about largely by the decomposition of marcasite, which is present in the clay. The weathered clay of the Grand Gulf could be used in many places in the mânufacture of brick. There are some out-crops which contain a very high per cent of finely divided silica. These clays not only lack bonding power, but they present difficulties in drying.

PEARL RIVER COUNTY.

GEOLOGY.

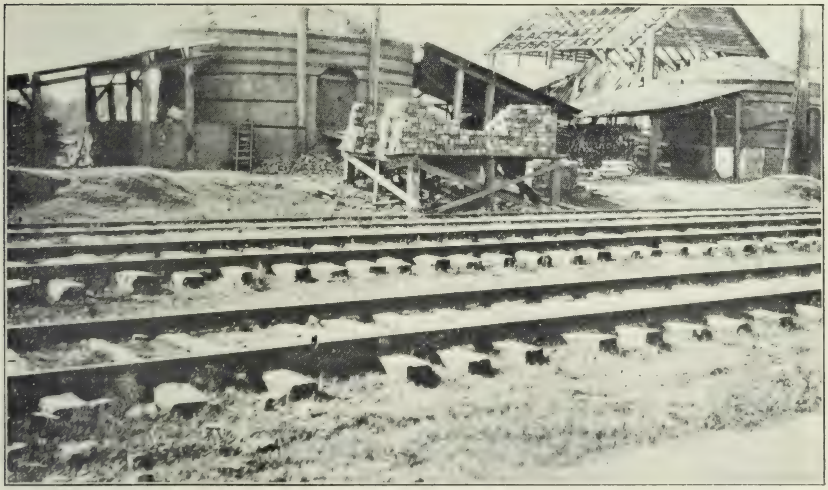
Pearl River County lies within the Grand Gulf area. The surficial rocks belong to the Lafayette and to the Columbia. Along Pearl River Valley there are also more recent deposits of alluvium. At Poplarville, one of the highest points between New Orleans and Meridian, the Lafayette deep-red sands have a thickness of about fifty feet. There is considerable gravel in the lower part of the formation, and the shallow wells obtain their water-supply from this gravel-layer. The quantity of gravel varies from point to point. The Grand Gulf clays are exposed along the branches of Abolo Chitto and other streams. The clays are often interstratified with beds of lignite or lignitic clay. Such beds are usually thin and contain considerable quantities of iron pyrites.

CLAYS AND CLAY INDUSTRY.

Lacy.—The surface clays of Pearl River County have been used in the manufacture of brick at Lacy. The clay was tempered in soaking pits and molded by hand. The bricks were dried in open yards and burned in scove kilns. The clay used belongs to the Columbia. It is of a light yellow color and of a sandy type. The Lafayette clays occur in

PLATE XV.

A. LAFAYETTE CAPPED WITH COLUMBIA LOAM, NEAR WOODVILLE.



B. FERRELL BRICK KILNS, OSYKA.

abundance in this county, and, doubtless, many of the out-crops contain clays suitable for the manufacture of brick. The Grand Gulf clays are, as a rule, not suitable for the manufacture of brick because of the difficulty in drying, but the residual clay of the Grand Gulf may be used n making common brick.

Caledonia.—Out-crops of Grand Gulf clay occur in railroad cuts on the New Orleans and North Eastern Railroad at Caledonia. The unweathered clays are not suitable for the manufacture of brick.

PIKE COUNTY.

GEOLOGY.

Grand Gulf strata underlie the surface of Pike County. The surface of the Grand Gulf is mantled with Lafayette and Columbia. The gray clays of the bed-rock are found in the sides and bottoms of the ravines which dissect the divides between the stream-courses. The Lafayette-reddish sands and clays contain large numbers of water-worn pebbles in some outcrops. The Columbia formation does not appear as thick here as in the counties nearer the Mississippi River.

CLAYS AND CLAY INDUSTRY.

The clays of Pike County, which have been used in the manufacture of brick, are surface clays belonging to the Columbia formation. The other clay-bearing formations are the Lafayette and the Grand Gulf.

Summit.—The plant of the Summit Brick Manufacturing Company was established in 1906. The clay used is a yellow, surface clay. It is brought from the pit by the aid of cable cars elevated by drum and hoist. The clay is pulverized by a granulator and a disintegrator. It is then tempered in a pug-mill and molded in a soft-mud machine, operated by steam-power. The bricks are dried on pallets in covered racks and are burned in clamp-kilns.

McComb City.—The White and Mey Brick Manufacturing Company established a plant at McComb City in 1897. A yellowish-gray, surface clay is used, which is transported to the plant by cars propelled by steam power. The clay is pulverized in a granulator and a disintegrator. It is tempered by passing it through two pug-mills. The bricks are molded in a soft-mud, steam-power machine. They are dried in shed-driers and burned in clamp-kilns of rectangular shape.

Fernwood.—The Fernwood Lumber Company began the manufacture of brick in 1890. The material used is a surface clay obtained from a small creek valley. It is probably of Columbia age. The clay is excavated by means of a steam shovel and hauled on small cars propelled by steam power. It is pulverized by the use of a disintegrator and a granulator. It is tempered by passing through two pug-mills, and is molded in a soft-mud, steam-power machine. The bricks are placed on pallets and dried in covered racks. They are burned in large, rectangular, clamp-kilns.

Osyka.—The Neff and Owen Brick Company of Osyka uses a yellow surface clay in the manufacture of brick. The clay is tempered in a ring-pit and molded by hand. The bricks are burned in rectangular and bee-hive up-draft kilns. The plant was established in 1892.

In 1897 Mr. S. R. Ferrell established a brick plant at Osyka. A surface clay is employed in the manufacture of brick by the soft-mud process. The clay is tempered in a ring-pit and molded by hand. The bricks are dried in sheds and burned in up-draft kilns of the bee-hive type.

Mr. J. C. Wilson began the manufacture of brick at Osyka in 1899. The method of treating the clay is the same as in the other two plants.

Magnolia.—In 1892 S. Cohn and Sons began the manufacture of brick at Magnolia. The bricks are manufactured by the soft-mud process. The clay is tempered in a ring-pit and molded by hand. The bricks are burned in rectangular, up-draft kilns.

SIMPSON COUNTY.

GEOLOGY.

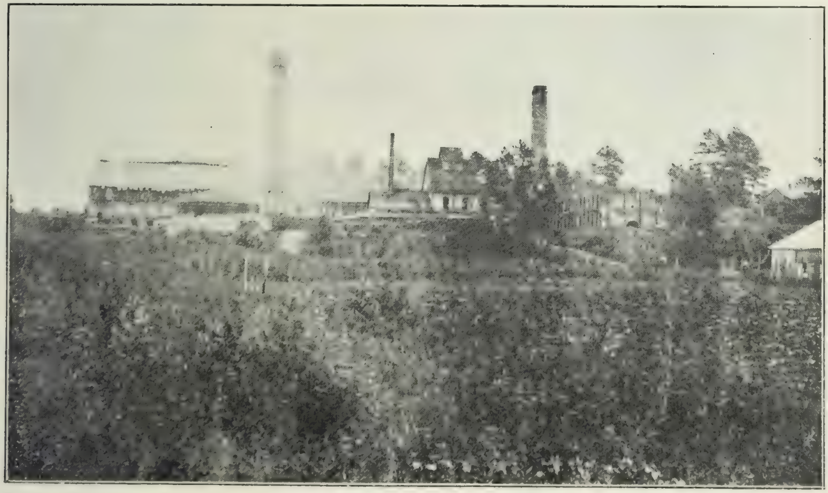
The bed-rock of Simpson County belongs to the Grand Gulf formation. The mantle-rock consists of Lafayette sands and gravels, Columbia loam and residual material from the older rocks.

CLAYS AND CLAY INDUSTRY.

The clays which may be utilized in the manufacture of brick in Simpson County belong to the mantle-rock and to the residual materials from the bed-rock. The Grand Gulf contains thick beds of clay, but these are not always suitable for the manufacture of brick until they have been properly weathered.

PLATE XVI.

A. GRAND GULF IN CREEK-BANK AT GOLDEN'S WATER MILL, TAYLORSVILLE.



B. STONINGTON BRICK MANUFACTURING PLANT, STONINGTON.

SMITH COUNTY.

GEOLOGY.

The northeastern part of Smith County is underlain by Jackson sands, clays and marls. The bed-rock of the central portion of the county is composed of Vicksburg limestone; the southern portion of the county is underlain by Grand Gulf strata. The bed-rock is mantled by deposits of Lafayette and Columbia and the residual materials of the bed-rock formations. In some localities the Lafayette has a white, chalk-like clay at the base. On Dr. Weatherby's farm, north of Taylorsville, the white clay is said to have a thickness of sixteen feet. On Deer Creek, at Taylorsville, layers of white sandstone of Grand Gulf age are overlain by variegated clays of Lafayette, over which is a layer of yellow sand or sandy loam (Columbia). The undrained areas of the Columbia contain a gray clay, with iron concretions called "buckshot."

CLAYS AND CLAY INDUSTRY.

The clay industry of Smith County has been but little developed. The clay-bearing formations are the Lafayette, the Grand Gulf, the Jackson and the Columbia.

Taylorsville.—Mr. G. Bustin at one time operated a brick plant at Taylorsville. The bricks were molded by the stiff-mud process. The material used was a mixture of yellow, surface clay, and a plastic clay from the Lafayette. The latter was taken from a pit at a depth of twenty feet below the surface. After an accident caused by the caving of the walls of the pit the plant was abandoned.

In 1906 Mr. M. S. Golden burned a kiln of soft-mud brick on his farm on Deer Creek. The following geological section is exposed near the pit:

Section on Deer Creek, Golden's Mill.

		Feet.
4.	Soil, sandy	1 to 2
3.	Loam, sandy (Columbia)	5
2.	Clay, variegated and stratified	5
1.	Sandstone, white	12

The clay from No. 2 was used in the manufacture of brick. It is deficient in bonding material on account of too much sand. A more plastic clay should be added to this in order to make a good brick.

The white Lafayette clay from the Weatherby farm, referred to above, has been used in the manufacture of brick and tile. Two

chimneys of a store building in Taylorsville were built of white bricks from that place. The bricks are said to be capable of withstanding a very high temperature. The composition of a sample of the clay is as follows:

TABLE No. 33.

ANALYSIS OF WHITE, LAFAYETTE CLAY FROM NEAR TAYLORSVILLE.

	No. 74 O. S.
Moisture (H_2O)	1.28
Volatile matter (CO_2, etc.)	6.60
Silicon dioxide (SiO_2)	71.29
Aluminum oxide (Al_2O_3)	16.78
Iron oxide (Fe_2O_3)	3.30
Calcium oxide (CaO)	0.14
Magnesium oxide (MgO)	0.41
Sulphur trioxide (SO_3)	Trace.
Total	99.80

RATIONAL ANALYSIS.

Clay substance	42.52
Free silica	45.55
Fluxing impurities	3.85

This clay requires 17 per cent of water to render it plastic. The shrinkage in air-drying is 5 per cent. Its specific gravity is 2.23 per cent. The unburned briquets have an average tensile strength of 100 pounds per square inch.

Burns.—Mr. T. B. Winstead of Burns uses a surface clay in the manufacture of brick. He uses the soft-mud process of molding and burns in scove kilns.

WAYNE COUNTY.

GEOLOGY.

The sub-strata of the northeastern part of Wayne County belong to the Jackson group. The area of the Jackson out-crop is marked by sticky lime soils and patches of bald prairie. The central part of the county is underlain by the Vicksburg limestone. The solvent action of ground water has produced a number of small caves in the rocks of this group. The largest of these is King's Cave, about seven miles northwest of Waynesboro, on Mr. Pitt's farm.

The Grand Gulf strata form the sub-surface of the southern portion of the county. The rocks of this group consist of white and red sands and bluish clays containing lignitized remains of trees.

The red sands and the variegated clays of the Lafayette form the principal mantle-rocks of the county. Along the divide between the

Chickasawhay River and Buckatuna Creek the hills are capped with Lafayette sands and ironstones. The Columbia loam is also present, mantling the older formations in most places. Two types are recognizable, gray and brown.

The analyses of two samples of Jackson marl, one from Chickasawhay River at Davis Ferry and the other from Limestone Creek are here given.

TABLE No. 34.

ANALYSES OF JACKSON MARLS, FROM WAYNE COUNTY.

	No. 1.	No. 2.
Insoluble matter	55.185	56.787
Alumina	1.956	.855
Lime	19.508	20.793
Potash	.621	.369
Soda	.129	.178
Magnesia	.950	.833
Brown oxide manganese	.192	.032
Peroxide of iron	1.194	1.928
Phosphoric acid	.080	.121
Sulphuric acid	1.804	.085
Carbonic acid	17.662	16.273
Organic matter and water	00.000	1.100
Total	99.666	99.351

A sample of Vicksburg marl from Lang's mill, in Wayne County, was analyzed with the following results:

TABLE No. 35.

ANALYSIS OF VICKSBURG MARL, WAYNE COUNTY.

Insoluble matter	23.282
Alumina	2.726
Lime	37.633
Potash	.295
Soda	.255
Magnesia	1.188
Brown oxide of manganese	.088
Peroxide of iron	2.200
Phosphoric acid	.119
Sulphuric acid	.312
Carbonic acid	29.500
Organic matter and water	2,524
Total	100.122

CLAYS AND CLAY INDUSTRY.

The clay-bearing formations of Wayne County are Jackson, Grand Gulf, Lafayette and Columbia. The last two named are being utilized in the manufacture of brick. The Lafayette clay is usually a stiff, reddish-colored clay. The Columbia is the surface formation. It is of a loamy nature, with a clay sub-stratum.

PLATE XVII.

B. POWER PLANT OF THE WAYNESBORO BRICK COMPANY, WAYNESBORO.

Waynesboro.—The Waynesboro Brick and Manufacturing Company uses a mixture of Lafayette clay and Columbia loam in the manufacture of brick. The plant was established in 1906 with Mr. H. H. Moore as superintendent. The stratigraphy of the clay-pit is as follows:

Section of Waynesboro Clay-Pit.

		Feet.
3.	Soil, about	1
2.	Columbia loam	2 to 3
1.	Lafayette clay, about	12

The total thickness of No. 1 is not revealed in the pit, but is said to be twelve feet thick in the well located in the yard. The well is eighteen feet deep, with sixteen feet of clay and two feet of sand. The sixteen-foot bed of clay is prepared by crushing in a granulator and disintegrator and tempering in a pug-mill. It is then molded in a stiff-mud machine of the horizontal, auger-type, and the bricks cut with an end-cut machine. The bricks are stacked in rows under covdered racks and dried. They are then burned in up-draft, clamp-kilns.

Analyses of Lafayette clay and Columbia clay used in these bricks are given below. No. 1 is from the Lafayette and No. 2 is from the Columbia:

TABLE No. 36.

ANALYSES OF WAYNESBORO CLAYS.

	No. 1.	No. 2.
Moisture (H_2O)	1.98	1.53
Volatile matter (CO_2, etc.)	5.13	2.37
Silicon dioxide (SiO_2)	75.12	83.33
Aluminum Oxide (Al_2O_3)	10.75	8.00
Iron oxide (Fe_2O_3)	4.57	3.50
Calcium oxide (CaO)	0.32	0.67
Magnesium oxide (MgO)	0.03	0.09
Sulphur trioxide (SO_3)	1.70	0.25
Total	99.60	99.94

RATIONAL ANALYSES.

	No. 1.	No. 2.
Clay substance	27.19	20.24
Free silica	58.68	71.29
Fluxing impurities	6.62	4.51

WILKINSON COUNTY.

GEOLOGY.

The bed-rock formation of Wilkinson County is of Grand Gulf age. The Grand Gulf rocks on the higher lands of the county are largely concealed by beds of gravel, sand and clay of Lafayette age and by the Columbia loams. Along the bluffs of the Mississippi River the older formations are mantled with a deposit of loess. The flood-plain area of the river is covered with alluvial silts of recent age. The bluffs of the Mississippi and Buffalo Bayou are composed of Grand Gulf and younger strata.

Dr. Hilgard, in his report on the geology of Mississippi, p. 150, gives the following section, which represents the stratigraphical condition of these bluffs:

Section at Loftus Heights, Fort Adams, Wilkinson County.

		Feet.
3.	Yellowish-gray, calcareous silt of Bluff formation (loess)	73
2.	Orange sand—yellow, orange and white sands	87
1.	Argillaceous sandstone, yellowish-gray in its mass, variegated with furruginous spots and veins, and of different degrees of hardness, so as to weather into rough, jagged surfaces. Traceable to water's edge	170

No. 3 represents the loess; No. 2 is Lafayette, at least in part, though a portion of the stratum may belong to the Grand Gulf; No. 1 is Grand Gulf.

CLAYS AND CLAY INDUSTRY.

The clays which have thus far been used in the manufacture of brick in Wilkinson County are surface clays of the Columbia formation.

Suitable clays for brick manufacture may be found also in the Lafayette and in the residual clays of the Grand Gulf. Bricks are now being manufactured at two points, Centerville and Woodville.

Centerville.—The Centerville Brick Manufacturing plant is owned and managed by Mr. G. W. Haag. The plant was established in 1897. The clay is prepared in a disintegrator and molded in a stiff-mud, end-cut machine. The bricks are stacked in sheds for drying. They are then burned in clamp kilns. The clay-bed has a thickness of about ten feet, the upper six feet of which is used for making brick. The bed of clay rests upon a layer of sand, the whole having a thickness of fifty-six feet, according to the record of a nearby well.

Woodville.—Mr. E. B. Arthur established a plant for the manufacture of brick at Woodville in 1903. The clay is tempered in a ring-pit. The bricks are molded by hand and burned in clamp kilns. The clay-pit exhibits a layer of sandy, Lafayette clay, capped with a brown loam (Columbia.) The full section of the clay is used from top to bottom.

TABLE No. 37.

SPECIFIC GRAVITY OF SOME MISSISSIPPI BRICK CLAYS.

Locality.	Formation.	Specific Gravity. Raw Clay.	Specific Gravity. Burned Clay
Agricultural College, No. 1	Residual Selma	2.18	2.20
Agricultural College, No. 2	Residual Selma	2.21	2.22
Agricultural College, No. 3	Residual Selma	2.13	2.45
Aberdeen	Lafayette	2.12	2.30
Amory	Lafayette	2.20	2.20
New Albany	Lafayette	2.15	2.36
Batesville	Columbia	2.10	2.40
Canton	Jackson	1.91	2.30
Canton	Lafayette	2.27	2.27
Clarksdale	Alluvium	1.93	2.11
Corinth	Residual Selma	2.20	2.22
Grenada	Columbia	2.04	2.31
Hampton	Alluvium	1.93	2.11
Hernando	Columbia	2.20	2.28
Holly Springs	Columbia	2.17	2.50
Houlka	Columbia	2.21	2.33
Indianola	Alluvium	1.90	2.15
Tchouticabouff River	Columbia	1.83	2.28
Macon	Porter's Creek	2.28	2.31
Morton	Jackson	2.12	2.22
Newton	Lafayette	2.00	2.31
Ocean Springs	Columbia	1.92	2.11
Pontotoc	Lafayette	2.33	2.25
Rienzi	Columbia	2.11	2.40
Ripley	Columbia	1.17	2.23
Vaiden	Claiborne	1.45	2.00

DIRECTORY OF MISSISSIPPI BRICK MANUFACTURERS.

	Name of Firm.	*Locality.*	*County.*
1.	Austin Brick Mfg. Co	Pontotoc	Pontotoc.
2.	Bacon Brick Mfg. Co	Greenwood	Leflore.
3.	Baldwyn Brick and Tile Co	Baldwyn	Lee.
4.	Beck Brick Mfg. Co	Vicksburg	Warren.
5.	Bledsoe Brick and Tile Co	Grenada	Grenada.
6.	Bonita Brick and Tile Co	Meridian	Lauderdale.
7.	Booneville Brick and Tile Co	Booneville	Prentiss.
8.	Brown Brick Mfg. Co	Crenshaw	Panola.
9.	Brookhaven Pressed Brick Co	Brookhaven	Lincoln.
10.	Blumer Brick Mfg. Co	Moss Point	Jackson.
11.	Buchanan Brick Co	Sardis	Panola.
12.	Bushman and McGinnis Brick Co	Hattiesburg	Forrest.
13.	Butler Brick Mfg. Co	New Albany	Union.
14.	Camp Brick Mfg. Co	Amory	Monroe.
15.	Carl Brick Mfg. Co	Grenada	Grenada.
16.	Centerville Brick Co	Centerville	Wilkinson.
17.	Charleston Improvement and Investment Co	Charleston	Tallahatchie.
18.	Clarksdale Brick and Tile Co	Clarksdale	Coahoma.
19.	Cline Brick Mfg. Co	Macon	Noxubee.
20.	Coffeeville Brick Co	Coffeeville	Yalobusha.
21.	Columbus Brick Mfg. Co	Columbus	Lowndes.
22.	Concord Brick Mfg. Co	Natchez	Adams.
23.	Corinth Brick Mfg. Co	Corinth	Alcorn.
24.	Crymes Brick Mfg. Co	Hattiesburg	Forrest.
25.	Edwards Brick Mfg. Co	Edwards	Warren.
26.	Erby Bros. Brick Co	Holly Springs	Marshall.
27.	Fernwood Lumber Co	Fernwood	Pike.
28.	Ferrell Brick Mfg. Co	Osyka	Pike.
29.	Furtick Brick Co	Rienzi	Alcorn.
30.	Garbish Brick Mfg. Co	Vicksburg	Warren.
31.	Greenville Brick Mfg. Co	Greenville	Washington.
32.	Gregory Brick Mfg. Co	Vicksburg	Warren.
33.	Gloster Brick Mfg. Co	Gloster	Amite.
34.	Gulo Brick Mfg. Co	Holcomb	Grenada.
35.	Hancock Brick Mfg. Co	Newton	Newton.
36.	Hawkins and Hodges Brick Co	Okolona	Chickasaw.
37.	Hazlehurst Brick Mfg. Co	Hazlehurst	Copiah.
38.	Howard Brick Mfg. Co	Starkville	Oktibbeha.
39.	Imperial Brick Company	Biloxi	Harrison.
40.	Indianola Brick and Tile Co	Indianola	Sunflower.
41.	Jesty Brick and Lumber Co	Winona	Montgomery.
42.	Langley Bros. Brick Co	Louisville	Winston.
43.	Laurel Brick and Tile Co	Laurel	Jones.
44.	Leakesville Brick Co	Leakesville	Greene.
45.	Liberty Brick Mfg. Co	Liberty	Amite.
46.	Landon Brick and Tile Co	Landon	Harrison.
47.	Love Wagon Co	Durant	Holmes.
48.	Lowery and Berry Brick Co	Blue Mountain	Tippah.
49.	Maben Brick Mfg. Co	Maben	Oktibbeha.
50.	Magnolia Brick Mfg. Co	Magnolia	Pike.
51.	Meadville Brick Mfg. Co	Meadville	Franklin.
52.	Montgomery Brick Mfg. Co	Senatobia	Tate.
53.	Montgomery Land and Brick Co	Yazoo City	Yazoo.

DIRECTORY OF MISSISSIPPI BRICK MANUFACTURERS—Continued.

	Name of Firm.	*Locality.*	*County.*
54.	Mt. Olive Brick Mfg. Co	Mt. Olive	Covington.
55.	Natchez Brick Mfg. Co	Natchez	Adams.
56.	Nettleton Brick Mfg. Co	Nettleton	Lee.
57.	Neff and Owen Brick Mfg. Co	Osyka	Pike.
58.	New Houlka Brick Mfg. Co	New Houlka	Chickasaw.
59.	Norfield Brick Mfg. Co	Norfield	Lincoln.
60.	Norris Brick Mfg. Co	Water Valley	Yalobusha.
61.	Oktibbee Brick Mfg. Co	Meridian	Lauderdale.
62.	Oxford Brick and Tile Co	College Hill	Lafayette.
63.	Orange Groove Brick Co	Orange Groove	Jackson.
64.	Pope Brick Mfg. Co	Houston	Chickasaw.
65.	Port Gibson Mfg. Co	Port Gibson	Claiborne.
66.	Quitman Brick Mfg. Co	Quitman	Clarke.
67.	Rheinhart Brick and Tile Co	Clarksdale	Coahoma.
68.	Ripley Brick Mfg. Co	Ripley	Tippah.
69.	Riverside Brick Mfg. Co	Hattiesburg	Forrest.
70.	Robinsonville Brick and Tile Co	Robinsonville	Tunica.
71.	Ruffin Brick Co	Columbia	Marion.
72.	Saltillo Brick Mfg. Co	Saltillo	Lee.
73.	Seavey and Sons Brick Mfg. Co	Brookhaven	Lincoln.
74.	Smith Brick Mfg. Co	Canton	Madison.
75.	Storer and Miller Brick Co	Louisville	Winston.
76.	Storer and Miller Brick Co	Kosciusko	Attala.
77.	Stonington Brick Mfg. Co	Stonington	Jefferson.
78.	Success Brick and Tile Co	Greenwood	Leflore.
79.	Summit Brick Mfg. Co	Summit	Pike.
80.	Sunflower Brick Mfg. Co	Indianola	Sunflower.
81.	Tanner Brick Mfg. Co	Vicksburg	Warren.
82.	Taylor and Thomas Brick Mfg. Co	Crystal Springs	Copiah.
83.	Taylor Brick Mfg. Co	Jackson	Hinds.
84.	Thrasher Brick Mfg. Co	Thrasher	Prentiss
85.	Thornton Brick Mfg. Co	Vicksburg	Warren.
86.	Tubbs Brick Mfg. Co	Amory	Monroe.
87.	Union County Brick Co	New Albany	Union.
88.	Utica Brick Mfg. Co	Utica	Hinds.
89.	Vaiden Brick and Tile Co	Vaiden	Carroll.
90.	Valley Brick and Tile Co	Lakeview	DeSoto.
91.	Vardaman Brick Co	Vardaman	Calhoun.
92.	Verona Brick Mfg. Co	Verona	Lee.
93.	Waynesboro Brick Mfg. Co	Waynesboro	Wayne.
94.	Weems Brick Co	Sun	Scott.
95.	Welch-Trotter Brick Co	West Point	Clay.
96.	West Point Brick Mfg. Co	West Point	Clay.
97.	White and Mey Brick Co	McComb City	Pike.
98.	Wilson Brick Mfg. Co	Osyka	Pike.
99.	Winstead Brick Co	Burns	Smith.
100.	Woodville Brick Mfg. Co	Woodville	Wilkinson.

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In the list given above are some of the more important works on the subject of clay. Some of those named are not given because of their importance as reference works on the subject of clay, but because they have a bearing upon the subject of Mississippi geology or clays. No attempt has been made to give a complete bibliography or to make complete the list of writings of any one author. Nearly all the articles on clay have been published in the reports of State geological surveys and are accessible to the clay-worker.

ACKNOWLEDGMENTS.

I desire to express my thanks to the men engaged in the manufacture of brick within the territory covered by this report for the generous and cordial way in which they have responded to calls for information necessary for the completion of this report. I am under very great obligations to Mr. A. F. Crider, Director of the Survey, for samples of clays, for reading the manuscript and for other courtesies extended.

The chemical work forming a very important part of the report was done under the direction of Dr. W. F. Hand, State Chemist, and to him and his corps of assistants all credit is due. A few chemical analyses derived from other sources are credited at their proper places.

To other citizens of the State who have kindly assisted me while engaged in the field work, I desire to express my full appreciation of their valued services.

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NOTE.

The manuscript of this Bulletin was submitted by Dr. Crider to the Publishing Committee in the Spring of 1908. Its publication has been unavoidably delayed until the present time. We regret to announce that in the meantime Dr. Crider has resigned the Directorship of the Geological Survey. His valuable work on Mississippi geology, however, will form a basis for future work for many years to come.

E. N. Lowe, *Director*.

A STUDY OF

Forest Conditions

OF

Southwestern Mississippi

BY

THE UNITED STATES FOREST SERVICE

IN COÖPERATION WITH

THE MISSISSIPPI STATE GEOLOGICAL SURVEY

BY

J. S. HOLMES, Forest Examiner

J. H. FOSTER, Forest Assistant

JANUARY, 1908

BRANDON-NASHVILLE,

LETTER OF TRANSMITTAL.

JACKSON, MISSISSIPPI, March 17, 1909.

To His Excellency, Governor E. F. Noel, Chairman, and Members of the Geological Commission:

GENTLEMEN: I submit herewith a report of the forest conditions of Southwestern Mississippi, by J. S. Holmes and J. H. Foster, of the United States Forest Service, and respectfully recommend its publication.

This is the only official report of the forest conditions of Mississippi, and while it deals with only a small area of the State, it throws much light on the subject and shows the need of further investigations.

Very respectfully,

ALBERT F. CRIDER,

State Geologist of Mississippi.

CONTENTS.

A STUDY OF FOREST CONDITIONS OF SOUTHWESTERN MISSISSIPPI BY THE UNITED STATES FOREST SERVICE, IN CO-OPERATION WITH THE STATE GEOLOGICAL SURVEY.

BY

J. S. Holmes, *Forest Examiner,*
J. H. Foster, *Forest Assistant.*

INTRODUCTION.

In 1907 the Geological Survey of the State of Mississippi requested the co-operation of the Forest Service of the United States Department of Agriculture in a study of the forest resources of that State, and made an appropriation of $500 for the purpose. It is the policy of the Government to assist States in investigating their resources, and the Forest Service duplicated the State appropriation and made a total of $1,000 available for the work, which was begun in November, 1907. The study was necessarily limited in scope, but with further appropriations by the State, which the Forest Service will be glad to duplicate, the study may be gradually extended to cover the entire State.

The longleaf pine region in the southern part of the State offered the most important field for a beginning. The future usefulness of the large areas of cut-over longleaf land, and the rapidly diminishing supply of timber were timely subjects for study and investigation.

This report deals with the forest conditions in the southwestern counties of the State, and includes a description of the several types of forest, a summary of the forest and economic conditions of each of the counties covered, and a review of the timber industries in the region. Plans for the conservative management of private and public forest lands are outlined, and recommendations are made for a definite forest policy for Mississippi.

The map which accompanies this report defines the western limit of longleaf pine in Mississippi and shows

the location and extent of the different forest types in the region covered. The shaded portions of the map show roughly the location of the areas on which the largest bodies of pine timber are still standing. It must not be inferred that all this area is heavily timbered, but the greater part of the remaining pine timber in this region does occur in these shaded areas.*

* A preliminary report on "The condition of Cut-over Longleaf Pine Lands in Mississippi," has been issued as Circular 149 of the Forest Service.

The area included in this study is approximately 6,200 square miles and consists of the following counties: Pike, Marion (West of Pearl River), Lincoln, Lawrence (West of Pearl River), Copiah, Franklin, Amite, Wilkinson, Adams, Jefferson and Claiborne.

THE REGION.

Geology and Soil.—The region consists of a rolling, more or less broken plateau which varies from 100 to 500 feet in elevation and falls off precipitously in the vicinity of the Mississippi River to the level bottom-lands.

The formations of this portion of the State are included within the later Cenozoic period of geological history and consequently represent the most recent deposits. These formations consist largely of Lafayette, Loess, Columbia, and the recent river deposits in the bottom-lands.

The Lafayette deposit consists of sands, gravels, clays, etc. It occupies the greater portion of southern Mississippi, and coincides with the longleaf pine belt. The thickness of the formation rarely exceeds fifty feet.

In the southeastern and southern portions of the State, the Lafayette clays occupy most of the uplands close to or on the surface of the ground. Toward the west they become deeper seated and are covered by brown and yellow Columbia loams. These loams are of considerable depth in the hill country and often represent the deposit since the clays were laid down.

Extending approximately northeast and southwest at varying distances, up to several miles, from the Mississippi River, there is a chain of bluffs which fall off rapidly toward the river on the west. This line of bluffs is made

up of the Loess formation of very fine-grained silt of a brownish color. The Loess area forms a narrow tract along the eastern border of the Mississippi Valley, widest towards the bluffs and gradually narrowing to the east until finally blended with the brown loams.

Between the Loess bluffs and the Mississippi River is the true Mississippi flood plain or "delta." This river level is narrow in the southern portion of the State, but widens to thirty miles or more toward the north.

From east to west across the State, then, the character of the soil changes, and in general, increases in value toward the Mississippi River. The nature of the tree growth is governed by the change in the character of the soil.

Transportation.—The transportation facilities throughout this region are excellent. Main lines of railroad penetrate each county, and bring the producer within fairly easy reach of New Orleans and Gulfport on the south, and Memphis, St. Louis and Chicago on the north. New lines are being completed which will further increase the facility for handling agricultural and forest products. The line traversing the region east and west from the Pearl River to Natchez will soon be in operation. These railroad lines have opened up the country for ten miles or more on each side of their rights of way. Beyond that, long and difficult wagon hauls are necessary. Along the Mississippi River transportation is entirely by steamboats and barges.

The large lumber companies located their mills along the main lines of railroad and began operations almost besides their mill yards. As the timber close at hand became exhausted, tram lines or dummy roads were extended toward the interior and the logs were hauled to the mills. These roads are now so extended that in many cases operations are being carried on thirty miles or more from the mills. Each county has been penetrated by numerous logging railroads, some of which are now permanent and of extreme value to the communities.

Except in certain portions of the hill country, railroads are not hard to construct and in no case is transportation a difficult problem. Railroad freight rates are not excessive and river transportation is still cheaper.

During the greater part of the year the principal wagon roads are good, but during the wet winter months the roads in many of the counties are in bad condition, and in some cases they become almost impassable. Each county decides on its own method of road maintenance, and most of them are not alive to the importance of keeping the roads in good condition. Adams County has excellent highways, which greatly benefit its citizens by cheapening the haul to market and by bringing trade from surrounding counties.

Good roads are a necessary part of conservative forest management, for by cheapening the means of transportation, the value of the products are proportionately increased.

Labor Conditions.—The farmer and the lumberman rely upon negro labor since the negro population varies from 40 to 60 per cent in the uplands and pine country, to 90 per cent in some sections along the Mississippi River. The lumbermen, as a rule, experience little difficulty in getting all the labor needed, since they can afford to pay more than most farmers. Wages for farm labor range from 75 cents to $1.50 per day. In the various lumbering operations the ordinary laborer gets $1.00 to $2.00 per day.

THE FOREST.

The whole of southwestern Mississippi was originally under forest growth. The first large clearings were made along the rivers, and the strip within reach of the Mississippi River was fairly well settled before any railroad entered the State. It was not until the Illinois Central, and later the Yazoo & Mississippi Valley, railroads were built, that the country back from the river was extensively cleared and settled, but since then, especially within the last fifteen or twenty years, the removal of the forest has been carried on at an ever-increasing rate. At present about one-third of this region is classified in the tax lists of the various counties as cleared, and fully one-third more has been cutover and left to grow up in oak scrub or anything else that can resist the frequent fires.

The forests of this region fall naturally into five divisions or types, according to the nature of the trees and the

various conditions under which they grow. These types are: pure longleaf, longleaf hills, hardwood hills, Mississippi flood plain, river and creek bottoms.

Pure Longleaf Type.—The pure longleaf pine forests occupy the drier and poorer soils of southwestern Mississippi. These soils are in the Lafayette clay formations, in which pebbles are often found in more or less stratified beds; the area includes the entire southern portion of the State as far north as Copiah County west of Pearl River. The pure longleaf type gradually merges into a mixed type of longleaf and shortleaf pine in Franklin and Amite counties to the west. East of the Pearl River the type is general over the entire southern region, extending nearly to the Gulf of Mexico. The region occupied by the "piney woods" is generally a rolling country, characterized by broad, dry plateaus occasionally cut by creek bottoms. The red or yellow clay is close to the surface over most of the uplands.

Longleaf pine, in pure, and mostly mature stands, is the chief merchantable tree. It grows tall and straight, without side branches for fifty feet or more from the ground.

In a mature dense forest of pure longleaf pine there is usually no reproduction. The ground is burned almost every year and no undergrowth will live. The mature trees do not appear to be injured by such fires, but their growth is undoubtedly checked, because of the destruction of the vegetable covering of the soil and the injury to the base of the trees.

Occasional small saplings or seedlings of oak are found growing beneath the pines, and often the ground is interlaced with roots of oak, although shade and fires prevent any material growth of brush. When the pine is cut off, this oak at once takes possession of the ground.

Loblolly and Longleaf Subtype.—On the moister situations throughout this region loblolly pine is found in mixture with the longleaf, forming a distinct variation from the main type. Loblolly, because of its more rapid growth in early life, survives on land where the surface water, at certain times of the year, would kill out the slower growing

longleaf. In such places there are open stands, usually with varying proportions of the two pines and sometimes a small admixture of stunted hardwoods. There is often an imperceptible gradation to the river and creek bottoms type, where the loblolly is an important tree.

The pine is of excellent quality, and the mature timber is mostly heartwood, which remains sound for many years. Except for a few twisted, or young, and inferior trees, nearly the whole forest is merchantable, and present operations leave few young trees standing on the ground after logging.

The stand varies. Severe winds have destroyed large numbers of the best trees in the forest, and culling the best trees for shingles or boards through many years has left most of the stands in an impaired condition. Over extensive areas old growth averages only about 5,000 board feet per acre, but occasional stands may average more than 30,000 feet per acre over limited areas. The general average over large areas of the best timbered counties does not exceed 10,000 to 12,000 board feet per acre.

Within this region naturally come the largest lumbering operations. Mississippi ranks third among the States producing yellow pine. Lumbering is on a gigantic scale. Each of six mills cuts more than 150,000 board feet per day, and there are many other mills cutting for local and export use.

Turpentining is carried on in several places, although the industry has not been developed so extensively as in similar forests farther east.

The enormous demand for longleaf lumber has resulted in the cutting of immense areas, so that from one-half to three-fourths of some of the counties have been cut over, and these are now burned and blackened stump lands. On some of these occasional longleaf pines have been left, but the ground is partly covered by worthless scrub oak, and in many places is littered with burned and partly rotten logs. Over large areas of the stump land there are enough remaining longleaf pines to seed the ground if fire is kept out. Still other areas are culled only, and there is enough timber left to pay for another logging.

Longleaf Hills Type.—The longleaf hill stype occupies a strip of country west of the pure longleaf pine area and runs northeast and southwest, from southwestern Copiah County through central Franklin County to western Amite and eastern Wilkinson Counties. It is, for the most part, a rolling, hilly country, with deep ravines and steep slopes. Some parts are level or gently rolling, but most of it is made up of narrow abrupt hills. The streams have cut deep channels, and erosion is much more extensive than in the pure longleaf region.

In these hills roads can be constructed only along the tops of the sinuous ridges, which are sometimes only wide enough for the purpose and drop away each side to narrow ravine bottoms. The soil is usually thin and not as rich as farther west, and the subsoil is a red or yellow clay often mixed with gravel. The more level portions have been extensively cultivated for many years, though the ravines and abrupt slopes are still covered with native forests.

The ravine and lower slopes for the most part are covered with hardwood forests. Oaks predominate, associated with hickory, sweet gum, ash, and others. Loblolly pine is scattered over these lower slopes, and the upper slopes and summits of the ridges are covered by shortleaf and longleaf pine with some loblolly and hardwoods. The more level portions originally had extensive forests of pine, with longleaf predominating to the east, but decreasing toward the west until it finally disappears entirely, giving way to the shortleaf, loblolly, and hardwoods.

Shortleaf pine is generally tall and straight, with but very little sapwood, and stands of this sort sometimes average 8,000 to 12,000 board feet per acre; but a general average for the type would be from 5,000 to 7,000 feet per acre.

These forests have been culled extensively for such products as white oak staves, and fence rails, but this practice has not everywhere prevailed, and splendid forests that average from 10,000 to 15,000 board feet per acre, still exist in remote localities. The longleaf pine in mixture in the northeastern part of this belt has largely disappeared. The country has long been settled and the easily accessible

timber removed. Some good stands of longleaf mixed with shortleaf and loblolly pine are still owned by small lumber companies, which are operating along the Yazoo & Mississippi Valley Railroad. In Franklin County there are extensive inaccessible areas not yet exploited, but which, with the completion of the Mississippi Central Railroad, will be made accessible. West of the Yazoo & Mississippi Valley Railroad are large tracts of hardwoods and shortleaf pine owned by lumber companies. These have not yet been extensively lumbered because of the difficulty in constructing tramroads into the hills.

No extensive areas of this region show the evil effects of recent logging. Reproduction of shortleaf and loblolly pine is generally good, and often a carpet of seedlings is conspicuous under the mature trees. Longleaf, however, does not reproduce very well. Only in a few places, where some of the old timber has been removed by lumbering or other causes, and where fire has been kept out, is there satisfactory reproduction of this species. There is seedling and sprout reproduction of the hardwoods all through the forest, but the shade of the pines, where they are plentiful, keeps this growth suppressed. Fires do much damage to reproduction, but owing to the broken nature of the country they are not so extensive or disastrous as in the pure longleaf type.

Hardwood Hills Type.—Between the hilly country occupied by mixed pine and the flood plain of the Mississippi River is located the hill and bluff region of loess or silt formation. This falls off abruptly to the Mississippi bottomlands on the west and on the east passes by imperceptible gradations into the pine hills. The soil is extremely fertile and increases in depth toward the cliffs. The slopes are usually steep and the ridges, especially in the western part, are very narrow. One of the chief functions of a forest on such situations, therefore, is to prevent erosion. This was among the first sections of the State to be settled and cultivated. Many years before the Civil War the forests on the more level and rolling land had been cleared for plantations, and today this is still one of the best agricultural regions of Mississippi. The forests are now

confined almost entirely to the slopes and ridges too steep for cultivation and to the abandoned fields now growing up with pine and hardwoods.

The original forest was entirely of hardwoods, and many persons living in the region remember when no pines were seen anywhere. The principal commercial species of this type are white oak, yellow poplar, ash, hickory, sweet gum, water oak, magnolia, beech, tupelo gum, and walnut. At the present time at least half of the area of the type contains a mixture of loblolly and shortleaf pines with the hardwoods while the old fields are usually occupied by pine to the exclusion of merchantable hardwoods. Heavy stands are found in some places, but the whole region will not average over 2,000 to 4,000 feet per acre for all the forest land. The forests have been culled to such an extent for local and export use that there is practically no virgin timber left, except in the most inaccessible situations. The young growth comes up rapidly, however, and is tall and straight, so that there is often a good stand of small thrifty trees where cuttings have been made sometime ago.

Reproduction of the better species is usually excellent. Ash, sweet gum, water oak, and hickory are especially abundant. Both species of pine seed reproduce freely where seed trees are present, so much so that in some places there is a probability that the hardwoods will be eventually crowded out. A dense undergrowth of cane, often found among the river hills, seriously hinders reproduction, but furnishes excellent winter pasturage for cattle.

The second growth forests, which come up on abandoned fields, vary considerably from those of original growth, almost justifying their separation into a different type or subtype. Two variations of the oldfield growth are found, hardwood and pine. The hardwoods come in on abandoned fields more slowly than the pine. They are usually of the poorer species, such as sassafras, hackberry, plum, and the inferior oaks, and it is only after many years that a stand of the better species, such as yellow poplar, white oak, and hickory becomes established. Black locust comes in naturally and is one of the most valuable and fastest growing trees in this type, but it is liable to serious damage by fire and insects.

Where seed trees are near enough, old fields usually seed up with loblolly and shortleaf. These grow faster than the hardwoods and form a much denser stand. Their relative proportion in mixture varies according to the available seed trees and to the quality and moisture content of the soil, the loblolly preferring the deeper, moister soil. These old fields are frequently used for pasturage, and the grass is burnt off to improve the range. As a result the pines are often sadly injured and the soil impoverished.

Mississippi Flood Plain.—All the bottoms and swamps lying between the Mississippi River and the "cliffs," or loess hills, are subject to overflow or would be overflowed were they not protected by the levees. The most extended areas lie about the mouths of the larger rivers, such as the Big Black and Homochitto, where water from the Mississippi often backs up these streams for many miles, flooding the country on either side. The greater part of this area is submerged only in times of high water, but much of the low swamp land is under water the greater part of the year.

The soils of these overflowed lands are alluvial deposits of sandy loam, varying to clay loam. Where a stream carrying sediment overflows its banks, the water begins at once to lose its velocity and deposit the sediment. The coarser and heavier particles of its suspended matter are deposited near the streams, while the finer particles are carried longer in suspension and are dropped farther from the main channel. It is for this reason that the land nearest the river is often higher and better drained than that farther back. The former is probably the richest land in the country and, where it can be drained and protected from overflow, it is being rapidly cleared for cultivation.

As the currents of the Mississippi tear away the banks and make new deposits, the course of the river is constantly changed. Much of the newly-formed soil seeds up with cottonwood and willow, the seeds being carried with the overflow on the surface of the water and deposited as the water receded. This results in even-aged and pure stands of these species over large areas of the Mississippi

River country. Later many of these areas seed up underneath with sycamore, elm, red oak, and other hardwoods, which in time replace the cottonwood and willow. Overcup oaks, gums and cypress finally take possession of the poorest drained soils. Cypress and tupelo gum are found mostly on land that is flooded throughout the year.

Originally, the timber on these flood plains was of magnificent size. Even yet cottonwood is being cut which yields 2,000 board feet per tree, and stands of mature cottonwood often yield from 20,000 to 30,000 feet per acre. Undoubtedly some of the original cypress and gum stands averaged 50,000 feet per acre. At present, however, there is little virgin timber in this type, much of it having been culled over several times. Often all timber that will float, such as cypress, cottonwood, willow, ash and oak has been taken, and only the gum and some inferior species left. On many of the plantations some cypress has been reserved for home use, as this furnishes the material most used for fencing, barn building and general repairs.

On most of these bottom-land swamps there is little reproduction because of the excess of water through the greater part of the year. On the better-drained soils, such undergrowths as cane, green brier, and dwarf palmetto, and the density of the forests, greatly interfere with the reproduction of the species that cannot endure shade. The rate of growth is generally rapid, especially on the better drained soils, but cypress always grows slowly. Fire sometimes runs over the drier land in the summer season, but the fire danger is not serious.

River and Creek Bottoms.—The chief rivers of this region are the Pearl, Homochitto, Black, Bogue Chitto, Amite, Bayou Pierre and Buffalo Bayou. The soil and moisture conditions of the bottom bordering these streams, their tributaries and other creeks vary so much from the surrounding country, and even from the Mississippi flood plain, with a consequent variation in the nature and composition of the forest, that these bottoms give rise to a practically separate type. In many cases, however, they are so narrow, often only a strip on one or both sides of the

stream, that this type cannot be accurately marked on the map.

The soils of these bottoms vary according to the size and location of the stream, the elevation of the land above the stream level, and the rate of the streamflow; all contain a considerable amount of organic matter and are quite fertile. For this reason much of the type has been cleared, and the rest of it will undoubtedly be used for agriculture as soon as the land can be successfully drained.

The forests are composed mostly of hardwoods and differ from those of the Mississippi bottoms chiefly in the entire absence of cottonwood and willow stands, and in the presence of loblolly pine on all but the lowest ground. Cypress, tupelo gum, ash, sycamore and elm flourish on the lower, poorer-drained soils, while loblolly, oaks, sweet gum, magnolia and beech do better on the warmer soils. Growth is rapid, especially on the well-drained soils. Most of this bottomland type has been culled over, especially for cypress, the greater part of which has been cut and floated down stream to market. There is some old growth loblolly of large size still to be found, chiefly along the smaller water courses, and young growth comes in very rapidly on abandoned old fields, as in the other hardwood types. Oak and gum now form the larger part of the commercial timber in this type, as there has been very little demand for these species for local use, and they can only be used for shipment where transportation facilities are good.

Reproduction on these bottoms is usually excellent, especially of the smaller seeded species, such as loblolly, tupelo and sweet gum, ash and sycamore. Much oak seed is eaten by the hogs that range over the bottoms and are fattened altogether from the mast of oak, hickory and beech. Fire, though rarer in the bottoms than on the dry uplands, often does great injury, especially to the reproduction.

CONDITIONS BY COUNTIES.

The question of the method of management to be employed in any certain case depends upon the forest type, the local markets and means of transportation, the present condition and ultimate purpose of the forest and other minor

considerations. In the following description of conditions in each of the counties included in this study, these points are touched upon in order that local conditions may be understood and that the recommendations given elsewhere in this report may be intelligently applied in individual cases. In these descriptions the proportion of cleared to forest land in the various counties was, in most cases, taken from the county records and checked up as closely as possible by the personal investigations of men in the field.

Pike County.—Pike County, with an area of approximately 450,000 acres, of which about 30 per cent is cleared, lies entirely within the pure longleaf area. It is for the most part a gently rolling country with a variation in elevation of not more than from 100 to 150 feet. Originally the county was covered, except for the bottomlands, with pure longleaf pine. The Bogue Chitto River, the bottomlands of which once contained magnificent hardwoods and cypress, passes through the center of the county. The Illinois Central Railroad passes through the western portion, and at frequent points along this line lumber companies have established sawmills and built tram lines east and west from the main line of railroad. Longleaf pine is lumbered almost exclusively.

There are only two types of forest in Pike County, the longleaf uplands and the bottomlands. The former covers extensive areas, probably 80 per cent of the county, of which at least one-third is still well forested. The bottomlands have been extensively cleared for cultivation, and there is little merchantable hardwood now found there.

The eastern half of the county still contains large areas of excellent pine. All this timber, however, is in the hands of a few lumber companies which are rapidly exploiting it. Three lines of logging railroad penetrate the timber from the Illinois Central Railroad, and another is reaching up from the mills at Bogalusa, Louisiana. Small mills are lumbering isolated areas, or removing the timber left on areas that were lightly culled some years ago. Many of these culled stands contain 2,000 to 3,000 board feet per acre. Virgin stands in the eastern townships yield from 10,000 to 30,000 feet per acre on small areas. Farmers are

getting an average of $20 an acre for pine lands. Some acres have sold for $50. Stumpage is about $2 per thousand, or from $5 to $20 per acre. Approximately 420,000 board feet of longleaf pine are cut daily for export use from mills located along the line of the Illinois Central. Some of this timber, however, comes from other counties.

In the past two or three years great damage has been done to the standing longleaf pine of this county by windstorms, especially in moist sags within the plateau regions. Probably 100,000,000 feet of fine timber have been destroyed.

Much of this pine land is valuable for agriculture, but it may not be cultivated, because not needed, for many years to come. So far, cultivation has been carried on chiefly within from six to ten miles of the railroad.

Turpentining is practiced more extensively in Pike County than in any of the other counties west of the Pearl River. Tylertown is the center for the orchards of the Fernwood Lumber Company, and considerable turpentining is also done in the northern townships. Railroad ties are cut from old field pine and also from standing dead trees or heart pine. They are sold at 25 cents each at the railroad. Cordwood sells at about $1.25 per cord where there is demand for it.

Years ago most of the school lands were leased and the lessees disposed of the standing timber. The schools of the county have thereby been deprived of a good source of revenue which would now be coming in from these pine lands.

Marion County (*west of Pearl River*).—Western Marion County, between Pike County and the Pearl River, is one of the few areas in Mississippi which still remains heavily timbered. It is a continuation of the longleaf region of eastern Pike County not yet lumbered, and consists of longleaf upland and narrow intervening creek bottoms covered with hardwoods, mostly of second growth. Considerable areas of bottom-lands skirt the Pearl River, although along some portions of it the banks are more or less precipitous.

There are approximately 63,000 acres of cleared land and 137,500 acres of uncleared land in this county west of the Pearl River. Of the uncleared area probably 60 per cent consists of merchantable timber, mostly longleaf pine. It is estimated that there are only 800 to 1,000 acres of true stump land in this area at the present time. Many thousands of acres of pine land, however, have been culled over in the past, and cannot now be classed as first quality pine land. Extensive areas have been boxed for turpentine, and the trees left to blow down or burn up, because of the absence of any lumber industries to use the boxed trees. There is comparatively little of the old field pine type.

This western portion of the county is largely a high, dry plateau, extending eastward from McGee's Creek, in Pike County, and falling off more or less abruptly to the Pearl River bottom-lands. Lumbering has scarcely begun over this longleaf pleateau land. The timber is owned by several lumber and realty companies which will eventually log the land from the tram lines approaching from the Illinois Central Railroad, and from the New Orleans Great Northern Railroad, recently constructed northward from New Orleans along the Pearl River. A branch of this line running to Tylertown from Louisiana will carry out much of the timber.

The timber has suffered severely from cyclones within recent years, but there are stands which still run 30,000 board feet per acre.

As yet there are few timber industries in the county. Turpentining will increase greatly as logging commences. Ties are cut from the townships bordering on the Pearl River that are mostly accessible to the railroad now being built.

The longleaf pine land is assessed at from $10 to $15 per acre and stump land at from $3 to $5 per acre. Agriculture has been but little carried on in these uplands, and the population is scattered. There is much fine agricultural land along the Pearl River and at the base of the uplands, and the larger part of the cultivated land is naturally there. The new railroad through this county will develop the

agricultural resources of this section as well as afford transportation facilities for the large undeveloped timber supply.

Lincoln County.—Lincoln County lies almost entirely within the longleaf belt. It was once heavily timbered, but today its timber is practically exhausted. The topography is gently rolling to level, and the changes from upland to stream bottom are seldom abrupt. The region is well drained by numerous streams. About 113,600 acres are classified as cleared land, while 259,000 acres are uncleared. Of this uncleared area only about one-quarter, or less than 18 per cent, of the entire area now supports a growth of merchantable timber, while the rest has been culled or remains as unproductive stump land, blackened by repeated fires and produces, at best, only an inferior quality of oaks and other hardwoods. The cleared lands consist of cultivated creek bottoms, the more level portions of the uplands and old fields. These old fields are abandoned because of erosion or impoverishment of the soil, and are now growing up to loblolly pine, which is frequently mixed with young hardwoods. There are no extensive areas of hardwood bottoms which have not been culled for more valuable oaks, hickories, poplar and cypress. Second-growth loblolly on old fields frequently attains considerable size, and is being cut for lumber. A growth of 12 inches in diameter in twenty-five years is not at all infrequent.

The Illinois Central Railroad passes through the county from north to south, and many years ago opened up the country for farming and lumbering. Logging has been done on the most extensive scale. The total estimated capacity of the principal mills operating along the Illinois Central Railroad in this county amounts to 700,000 board feet of longleaf pine per day in the form of lumber, shingles, laths, etc. Lumbering on such a scale has taken almost all the longleaf pine in the county. Operations are now chiefly confined to small bodies of timber in the southeast townships.

Recently the Mississippi Central Railroad has been constructed through the county from the east, which will give direct connections between Hattiesburg and Natchez,

and this will greatly foster the agricultural development of the county. Tram lines have penetrated every portion of the county and many of them now are hauling logs from adjacent counties to the mills along the Illinois Central Railroad.

The region has no valuable reproduction. Barely one per cent of the stump land is free from annual fires, and new growth is confined almost entirely to old fields. Much of this land will in time undoubtedly be brought under cultivation, but a great deal of the stump land will remain idle until intensive methods of farming are more generally practiced.

Lawrence County (west of Pearl River).—The topography of the western part of Lawrence County is similar to that of Lincoln County, except for the strip of bottom-lands adjacent to the Pearl River. With an approximate area of 156,000 acres, only about 34,000 acres, or a little more than 20 per cent, is listed as cleared land. In portions of the Pearl River bottom-lands and the vicinity of creeks the cleared land is extensive, and upland cultivation is also considerable. The uncleared land consists of hardwood bottoms, isolated stands of longleaf pine, and stump land. A large proportion of the longleaf uplands has been logged within recent years. In this county the lumber industry is nearly gone. The only remaining longleaf pine stands are in the four southern townships and a few isolated holdings in the northern part of the county.

The New Orleans Great Northern Railroad passes through the county close to the Pearl River, and the Mississippi Central crosses it from east to west. These railroads, with the line connecting Monticello and Brookhaven, greatly facilitate the development of the county. The lumbering is done over dummy lines extending from the Illinois Central Railroad. The longleaf pine timber remaining will be exhausted within a few years, and possibilities for agriculture are excellent.

Pine land is assessed at $15 per acre, cultivated land at $10 per acre, and stump lands, old field and hardwood land at $5 per acre.

Copiah County.—The forests of Copiah County vary from pure longleaf in the southeast to the hardwood hills in the northwest, but the greater part of the county is occupied by the longleaf hills type. This variation in forest type corresponds to the change in the character and formation of the soil. While the southeastern portion of the county contains the Lafayette red clays, the northern part consists of silts or loess of great fertility. Between these extremes, the soil changes gradually. This change marks the limit of longleaf pine as a pure type, for in the fertile soils of the silt formation the species is rare. North of this transition area, hardwoods formerly occupied much of the land. The county is nearly level or gently rolling, and much of it has been cultivated for many years. It comprises an area of 442,000 acres, of which nearly 70 per cent is cleared. A considerable amount of the land classed as "cleared," however, contains old field pine and second-growth hardwoods. The uncleared area contains pure and mixed longleaf pine and hardwoods. Very little of the merchantable hardwood is left. Practically all the pure longleaf pine in the county is now held in the four southeast townships, which contain 65 per cent of the virgin pine of the county. It is being lumbered from the vicinity of Wesson, on the Illinois Central Railroad. The New Orleans Great Northern Railroad will be the means of opening up the region along the Pearl River. In the southwestern portion of the county the longleaf is of poorer quality and in mixture with shortleaf. South of Hazelhurst, along the Illinois Central Railroad, was once a longleaf country, but the timber has been removed. Local sawmills scattered about the county are cutting old field pine and scattered virgin timber, both pine and hardwoods. Agricultural land is extremely valuable, and is often worth $30 to $50 an acre. Northern Copiah County is devoted largely to agriculture and is becoming noted as a truck-raising district.

Franklin County.—Franklin County has an area of about 380,000 acres. Less than one-fourth of it is listed as cleared land, much of which is now reverting to a sceond growth of pine. The western border of the longleaf pine region runs in a southwesterly direction through this county. The

pure longleaf type, which covers about 10 per cent of the total area of the county, extends only into its extreme southeast corner. This has nearly all been cut over within the past five years. The greater part of it is now practically denuded of pine and is supporting only a scrubby growth of the inferior species of oak. Very little of this land has as yet been cleared for agriculture. If seed trees of pine had been left when the lumbering was done a good growth of pine might now be coming in, to take the place of the forest removed. This corner of the county is so far distant from lines of railroad that it will probably be many years before much of it will be much needed for agriculture, and a second crop of valuable timber coming on the land would have been of great profit to its owners and to the county.

The longleaf hills type covers over half of the county. Owing to the mixed character of the forest, the broken nature of the country, and its remoteness from the railroads, the greater part of the timber is still standing. Longleaf is the predominant species, and forms from 50 to 70 per cent of the stand over large areas. The timber is sound and healthy, but it is not as tall as the longleaf farther east. It is for the most part confined to the top and upper slopes of the hills. Shortleaf and loblolly pine in varying proportions make up about 30 per cent of the forest. On the average about 10 per cent of the stand is hardwood, such as white oak, yellow poplar, sweet gum and hickory, which occur mostly in the hollows and lower slopes of the hills. On some areas, however, more than half the timber is hardwood. Lumbering, except for local use, has been confined to the pure longleaf type and to several places along the Yazoo & Mississippi Valley Railroad in the hardwood hills type, reaching into the longleaf hills in only one or two places. But with the construction of the Mississippi Central Railroad and with the gradual exhaustion of longleaf in other sections, a good many mills are starting up, while several large companies are buying all the timberland available. Franklin will in a short time be one of the largest lumber-producing counties in the region. The greater part of the longleaf hills type is possibly better fitted for the

growth of forest than for field crops, and so in all logging operations care should be taken to perpetuate the forest by leaving seed trees, by preventing injury to young growth, and by fire protection.

The hardwood hills type lies along the western and northwestern borders of the county and covers barely one-third of its total area. This part of the county has furnished most of the stave timber which has been, in the past, one of its chief timber outputs. A large portion of this section has been cleared for agriculture, but much land has been allowed to revert to forest. These areas, now grown up in loblolly pine, are furnishing practically all the railroad ties of the county. In the past year this industry has more than doubled its output, and now there are five or six mills for cutting ties in this part of the county.

The Homochitto River runs through the county, and there are considerable areas of bottom-lands along this stream and its tributaries, though probably not over five per cent of the county is in this type. Some good blocks of timber, consisting of oak, gum, loblolly, etc., are found, though lands which are dry enough are being cleared for agriculture. Cypress, which was once plentiful through these river swamps, has mostly been cut out and floated down the river to market.

Franklin County is developing its agricultural resources year by year, but for some time there will be considerable land on which it will be more profitable to grow timber. With the great increase in the lumber output, which has already begun, especial care should be taken to log such land conservatively, while fire protection should be undertaken by the owner and encouraged in every way by the county.

Amite County.—Amite County includes all of the forest types except the Mississippi bottoms. The pure longleaf type extends over the eastern half of the county. The western half, except for the southwestern townships, is covered by the longleaf hills type. The southwestern part of the county is largely cleared, and resembles the more level topography of Wilkinson County. It is classed as hardwood hills. The county has an area of 443,000 acres,

of which only about one-fourth is listed as cleared land. The greater part of the land under cultivation is in the western half, where the soil is much more fertile, and agriculture has been engaged in for many years. The soil here is influenced to a great extent by the loess silts. The eastern half of the county consists of dry longleaf pine uplands with frequent narrow creek bottoms. Pure longleaf pine formerly covered these uplands, and lumbering began many years ago on a small scale. Dummy lines were constructed from points on the Illinois Central Railroad. At first only the finest timber was removed, but present operations leave practically no pine timber on the land. There is still some good timber not yet lumbered, and there are other large areas which have been culled.

It is estimated that one-half of the longleaf uplands have been cut over and are now mostly stump lands. Probably one-fourth of the timber was culled out or destroyed years ago, and today these lands either still retain some longleaf pine or have grown up to hardwoods and loblolly pine. The remaining one-fourth of the original longleaf pine is still uncut and will last probably from ten to fifteen years.

West of the center of the county the longleaf pine is largely mixed with loblolly and shortleaf. The country is rough and extremely hilly in places. Farming is carried on extensively toward the western county line and in the southwest. The northwestern portion extending into Franklin County is heavily timbered with mixed pine and some hardwoods. This is in the hands of large companies.

There are over thirty small mills in the county cutting lumber, mostly for local use. Some hardwoods are being cut for foreign export. There is very little hardwood remaining in the county outside the northwest section. Turpentining is carried on to some extent east of Gillsburg.

On the longleaf uplands, areas cut over several years ago, often containing 1,000 to 3,000 board feet of timber per acre, can be bought for $5 per acre. Small mill owners often buy these areas from the big companies. This county is being rapidly stripped of its timber, and the largest companies will cut their supply in a comparatively few years.

Tie cutting is general. In the east the ties are largely disposed of to the Liberty White Railroad, and in the west they are hauled to the line of the Yazoo & Mississippi Valley Railroad. Most of the county is accessible to one or the other of these railroads.

The county shows considerable interest in the care of its school lands. Most of the timber on the sixteenth sections was cut many years ago, when pine was considered valueless and its removal a benefit. These old cuttings are past redemption now, but where school timber still remains it is being preserved. Three recent cases are reported where the county has been reimbursed for timber removed on rented lands. Eight townships in this county are receiving money from their school lands.

Wilkinson County.—Wilkinson County, with an area of a little more than 400,000 acres, occupies the extreme southwestern corner of the State. It is essentially an agricultural county, 63 per cent of the land being listed as cleared. All types but the pure longleaf, which does not extend as far west as this county, are represented. The longleaf hills type covers the northeast corner of the county north of Buffalo bayou. The stand on this type averages 5,000 to 7,000 feet per acre. The soil is not as fertile as that in the other parts of the county, and the hills, though short, are steep and liable to wash, so that the greater part of this area is more suitable for forest growth than for any other purpose. Longleaf pine is the principal timber tree, though in some areas, especially near the railroad on the eastern boundary, most of this species has been cut out, leaving loblolly and some shortleaf the predominating trees. Where fire has not passed over the ground lately, the reproduction of loblolly and shortleaf is excellent, and on some old cuttings longleaf also is reproduucing very satisfactorily. It is probable, therefore, that with careful management no trouble would be experienced in keeping any part of this corner of the county in a permanently producing forest.

The greater part of the county is covered with the hardwood hills type. In the western half of the county the hardwoods are in almost pure stands, while in the eastern

part they are mixed with loblolly and some shortleaf pine. The land produces excellent crops of cotton, so that only the steep slopes from which the soil will wash away, if cleared, should be kept in permanent forest growth. The trees to be encouraged are yellow poplar, ash, hickory and sweet gum.

On the Mississippi flood plain, and on the river and creek bottoms, the only land more suitable for forest growth than for agriculture is that which is too wet to cultivate. It will eventually be drained and put to its highest use, but in the meantime it should be kept in forest and the young growth protected when the mature timber is cut.

Lumbering has not been carried on extensively in Wilkinson County, and practically all the lumber cut has been for local use, except on the Mississippi bottoms, where it has been floated or shipped on the river. One line of railroad enters the county, a branch of the Yazoo & Mississippi Valley Railroad coming up to Woodville. Along this branch, and near the eastern border of the county close to the main line, ties are being cut in considerable quantities, mostly from loblolly. The production of white oak staves has for some years been the largest lumber industry in the county, but now there is little accessible timber left suitable for this purpose.

Adams County.—The eastern part of Adams County is rough and hilly, and characterized by the steep ridges and narrow ravines of the hardwood hills type. To the west the land becomes more rolling, cut by deep ravines and marked by excessive erosion. Bordering the Mississippi River the general level of the land drops abruptly to the bottomlands by a range of steep hills, or "cliffs," extending through the county. The overflowed Mississippi bottoms are chiefly in the southwest part of the county where the river backs up into the Homochitto River and floods large areas, sometimes during the entire year. The soil of the county is everywhere influenced by the silt or loess loams which increase in depth near the cliffs. Alluvial soil occupies the area between the cliffs and the Mississippi.

Much of the hill section of the county is still heavily timbered with pine and hardwoods. The difficulty of logging the inaccessible ravines and ridges has thus far pre-

vented lumbering, except for selected logs for export. West of the hill section, once entirely hardwoods, the county has been largely cleared and cultivatd. Immense plantations are common surrounding Natchez, and much of this land is without much tree growth. Old field pine, however, as elsewhere on similar lands, takes possession of abandoned fields. The bottomlands along the Mississippi are either in cultivation or occupied by stands of cottonwood, oak, gum and other hardwoods. Throughout the Homochitto overflowed lands, there are still some splendid bottom-land forests of cypress, gums and oak. A considerable amount of this type has been cultivated and many of the forests culled of their best timber. At present 29,000 acres along the Homochitto River are being drained for cultivation. Approximately 132,000 acres, or half the area of the county, is listed as cleared land. The uncleared land is confined to the eastern hills and the river bottoms. The assessment of the best agricultural land is sometimes as high as $33 per acre, with an average of $10. The uncleared land ranges from 50 cents to $7, with an average of about $5.

The timber of the hills type is mostly owned by a few companies, two of which are about to begin extensive operations. The merchantable trees, both hardwoods and pines, average about 5,000 board feet per acre. Reproduction is excellent, both of pine and hardwoods. Lumbering is being carried on in the Homochitto and Mississippi bottomlands. About 85,000 board feet of cottonwood lumber are being cut daily by small mills along the Mississippi, besides about 60,000 board feet of logs which are taken from the Homochitto region and rafted to Louisiana. Cypress and gum are also being lumbered from the bottoms. The growth of cottonwood is extremely rapid, and the tree reaches merchantable size in from 15 to 25 years. Many cottonwood stands will cut from 12,000 to 25,000 board feet per acre. Natchez is the great center of export for most products, and the Mississippi River offers the cheapest outlet for lumber. The Mississippi Central Railroad, when completed, will facilitate export through the center of the county.

It is estimated that 85 per cent of the swamp lands are still uncleared, though it is probable that all eventually

will be cleared for agriculture. The steepest parts of the hill section are absolute forest land, being too steep ever to become available extensively for farming. The remainder of the county will always be more valuable for agricultural purposes.

Jefferson County.—Except for the extreme southeastern part, Jefferson County is agricultural, and a large part of it is under cultivation. A high, somewhat broken plateau extends westward into the county and is occupied by mixed longleaf and shortleaf pine. This longleaf hills type quickly passes into the hardwood hills type as the land becomes lower and more level, and as the soil becomes influenced by the silty loams. The section west of the longleaf uplands, which comprises practically the whole county, was originally covered with hardwood of fine quality, much of which has long since been cleared. A large part of this section, however, has grown up again to loblolly and shortleaf pines. Approximately 146,000 acres, or nearly 52 per cent of the county, is classed as cleared land. The assessment of cleared land averages $4.50 per acre and uncleared land $4.

This was once a region of magnificent hardwoods, but much timber was cut and destroyed in clearing the land. Fifty years ago the whole region, except the swamps and longleaf uplands at the extreme southeast, was in a thorough state of cultivation, and plantations covering thousands of acres were common. But since the war much of the land has grown up to old field pine. Reproduction is prolific, and the growth exceedingly rapid, so that land once cleared but not now actually in cultivation, is covered with old field pine, either scattered or in fairly even stands. The average stand is about 2,000 to 3,000 board feet per acre, though some stands exceed 10,000 board feet. This land is being bought up by lumbermen and others for purposes of speculation.

Small mills have been operating for many years where the haul to the railroad is not too long. A great development of lumbering is about to take place in eastern Jefferson County, with the opening up of the Mississippi Central Railroad through Franklin County and a possible branch line

into Jefferson County. It is probable that within a few years lumber companies will be logging extensively throughout the eastern half of the county. Until recently there was no market for shortleaf or loblolly pine, but with the scarcity of longleaf pine and the consequent rise in prices of lumber, practically all the pines will be extensively logged in the future.

The only longleaf pine in this county is in the two southeast townships. This has been logged in a small way and the lumber hauled to McNair, on the Yazoo & Mississippi Valley Railroad, about twenty miles distant. The tie industry is important along the railroad lines. Small tie camps are established near good stands of loblolly and shortleaf pine, and are moved whenever the adjacent supply is exhausted. Many hardwood logs are hauled by farmers to the railroads and shipped to New Orleans and other points for special manufacture and for export.

Though the county is essentially agricultural, there is much land that should be kept permanently in forest. Such land would include the longleaf hills type and any other land that will wash badly when cleared. Much land in the hardwood hills type is very steep, and washes so badly when cleared with an incident loss of soil and fertility that it has to be abandoned in a few years to grow up to pine or hardwoods. On these situations the better quality of hardwoods, such as yellow poplar, ash, hickory and oak, should be encouraged, and also loblolly where it is abundant. This timber, in time, will be extremely remunerative.

Claiborne County.—Claiborne, with a total area of something like 320,000 acres, is essentially an agricultural county. Owing to its situation on the Mississippi River, settlement began early, and now probably 80 per cent of the area is cleared. A larger proportion of the cleared land is being regularly cultivated than in any other county in the region. With the exception of a narrow strip of overflow land along the Mississippi and the river bottoms, the whole of Claiborne County lies within the hardwood hills type. It is probable that the longleaf type at one time reached over into the southeast corner of he county, but with the clearing of most of the upland and the increased local demand for lumber, practically all of this species has now disappeared. The

southern and central part of the county is comparatively level or rolling and has been well cleared. Old field pine, therefore, forms the larger part of the present forest growth. To the north of Bayou Pierre and extending to the Big Black River, the hills are steeper and the country more broken, and there is a larger portion of forest land.

The old growth forest with an average stand of about 4,000 feet per acre is all hardwood, the chief species being white oak, hickory, yellow poplar, sweet gum, water oak and elm. Occasionally some old trees of loblolly are mixed with the hardwoods, which, together with the second growth shortleaf and loblolly already established, furnish seed for the reforestation of abandoned fields. The hills run out so close to the rivers both north and west that there is a relatively small area in bottom-lands, and hence there is very little cottonwood. Most of the bottom-land that is dry enough has been cleared for agriculture.

Local lumbering by small mills does not exceed an annual cut of two and a half million feet—nearly all old field pine. An average stand for old fields will not run over 3,000 to 4,000 feet per acre. An average stumpage price for second growth pine is about $1 a thousand, and the product sells for from $10 to $11 at the mill. The cutting and shipping of hardwood logs for export is the largest timber industry of the county. Many carloads go out each month over the two lines of railroad. Nearly the entire county is accessible to either rail or water communication, and at the present rate of cutting it cannot be very long before all the export timber is cut out. White oak staves are being cut to a considerable extent, and good, accessible stave timber is becoming scarce. Stumpage for stave wood runs from $1 to $2 a cord, and a stand of 1 to 2 cords to the acre is considered fair.

The only land in this county which can profitably be kept in permanent forest growth is that too steep for cultivation —the land which is now furnishing most of the export and stave timber. These two industries demand only the larger trees, so that, as a rule, all the smaller trees are left standing. With proper care in felling the timber and adequate protection from fire, these forests should yield a sufficient supply of timber for all local needs.

TIMBER INDUSTRIES.

Lumbering.—The lumbering of yellow pine is the most extensive forest industry in the State. As carried on by large concerns, it involves tremendous outlays for mills, machinery, railroad lines, locomotives and other miscellaneous equipment, besides an army of men. In 1906 the production of yellow pine lumber in Mississippi was 1,509,-554,000 feet, the total value of which was $24,387,901. Unfortunately this enormous industry is rapidly consuming its capital, the standing timber, without taking any steps to insure the production of a second crop. With the decline of the industry the southern part of Mississippi will gradually lose the most important of its present sources of wealth. Agriculture will develop as the country becomes more settled, but much of the land which will eventually be used for farming and which is now yielding nothing, can profitably be kept in forest growth for many years to come. Simple, conservative methods of forest management, such as leaving of seed trees and protection from fire, would undoubtedly pay the owners of yellow pine lands. The large operations are confined almost entirely to the pure longleaf type. Large mills are located only on important lines of railroad, from which the logging railroads or tram lines are constructed into timber. These often extend 25 miles or more from the mills.

Choppers are paid by the log or by the thousand feet. The logs are hauled to the spurs by steam skidders, or, if in inaccessible places, by team. They are left anywhere within 150 feet of the railroad, where the steam loaders pick them up. One steam skidder and one loader will usually handle about forty cars of logs a day. The cost to put logs at the mill varies from $2 to $4 per 1,000 B. F., exclusive of stumpage, divided about as follows:

Cutting	$ 50	$ 80
Hauling	60	1 30
Loading	20	40
Railroad haul	70	1 50
	$2 00	$4 00

The cost of manufacturing varies according to the size of the mill, equipment, etc. Large mills can manufacture more cheaply than the smaller ones, because they have equipment for utilizing the slabs and other waste in shingles and laths. The planing mill also lessens the cost by saving weight in the shipment of lumber. Lumbering by small mills often necessitates long hauls and requires a ready local market. Hundreds of such mills in the State supply the farmers with lumber and furnish employment for many local residents. Undoubtedly there will come a time when lumbering will be on a smaller scale than at present, when small stationary or portable mills will be used, as is now the case in many other parts of the United States.

The logging of extremely rough country is expensive, and it naturally is the last to be logged. It is often necessary to make long hauls with mule or ox teams, and operations must be on a relatively small scale. With such conditions conservative methods are most easily put in force, because the smaller trees will often not pay for the long haul, and the absence of engines in logging eliminates the most serious cause of fire. Methods of bottom-land logging vary with the location of the mill. In some cases, as with cottonwood along the Mississippi, the logs are hauled by team to the banks of the river, where the mills are located. Sometimes railroads are constructed into the swamps from the river. The lumber when manufactured is shipped in barges to important points, as Cairo, Cincinnati or New Orleans.

The cost of cottonwood lumbering varies about as follows:

	Per 1,000 B. F.
Cutting and hauling to the mill	$3 50 to $4 50
Sawing	3 00 to 3 00
Piling and loading on barge	50 to 1 00
Total	$7 00 to $8 50

A certain percentage of willow is often cut with the cottonwood, but it is worth considerably less. Willow stumpage is about one-third that of cottonwood, which varies from $3 to $5 a thousand feet. The manufactured

product sells for $12 per 1,000 and up, loaded on the barge.

There is more or less waste of wood in the lops and tops in all cottonwood operations, which might be very profitably utilized if there was a market for pulpwood near by. Above Memphis, pulpwood sells for $4.50 or more a cord. A plant for the manufacture of paper pulp, if erected at some point on the river between New Orleans and Memphis, would certainly have a large supply of raw material to draw from. A good market would thus be created for valuable material that is now wasted.

Many of the small holders of timber-land do not yet realize the value of stumpage, treating it as an asset like coal or iron, which, after it is once used up, is gone forever. Instead, it should be regarded as a crop and harvested in such a way that another crop would be assured. In selling standing timber, unless the intention is to clear up the land at once for crops, there should be some provision for the care of the young growth of the valuable species. It is a mistake to assume that timber cannot be sold unless the buyer is allowed to cut clean if he so desires. There is very little money in sawing small poles below say 10 or 12 inches, and so they are not usually cut where sold by the thousand board feet. Where, however, timber is bought by the acre, no stumpage charge is reckoned, and every tree is cut which will yield a profit over the cost of manufacturing alone. Cutting restrictions, providing for leaving the young growth, have been insisted on in several sales of timber in this region, and there is no reason why this should not be done in every sale.

Turpentining.—Turpentining should go hand in hand with lumbering longleaf pine. The forest should be so managed that trees may be boxed for several years ahead of the logging. Many companies have never turpentined their pine, because they were not sure how soon it would be logged. If lumbering follows the turpenting too quickly, the cost of erecting a still and boxing the trees is greater than the returns warrant. On the other hand, when logging does not follow the turpentining, the boxed trees are usually badly injured by fire and often blown down, so turpentining is most profitable when it can be started three or four years before logging begins.

The Fernwood Lumber Company turpentines its holdings about Tylertown, Pike County. There are also stills located in the northern part of the county and in Amite County. The largest operations in southwestern Mississippi are located in this region. The cup and gutter system is used extensively, though operators complain that the metal cups and gutters corrode and cause a discoloration of the resin, which reduces its grade. Malicious persons, and cattle, frequently knock off the cups. Much less injury, however, is done to the trees when the metal cups and gutters are used.

While the injury to lumber, which often results in lowering the grade of certain boards, and sometimes in butting off the first logs, is considerable, the profits from turpentine orcharding, in conjunction with lumbering operations, greatly overbalances the loss in lumber.

Tie Production.—Tie production is an important industry in southwestern Mississippi. In the longleaf belt, heart pine ties have been cut and used for many years, and many railroads use no other ties. But with the increase in the value of longleaf timber and the successful treatment of old field pine with creosote, the tie industry in the State is taking possession of the old field areas in the western counties, where the hauls to the railroad do not exceed four or five miles.

Loblolly and shortleaf pines are the principal trees used for ties in this section, though occasionally hardwoods of nearly every species are cut also. Timber for this purpose is largely second growth, since old growth is, for the most part, too far from the railroad to be cut into ties, and where close, it is usually too valuable for lumber. In good bodies of old field pine 250 ties per acre can be obtained, but from the immature stands, such as are usually cut, a yield of 50 to 100 ties per acre is more common. Probably more ties are now being sawed and hewed, and the proportion of sawed ties will no doubt increase owing to the adaptation of sawmill machinery to this special work, thereby cheap-

ening the cost of production. At present, however, the two methods cost about the same, as follows:

	Per Tie.
Stumpage	2 to 4 cents.
Cutting and making........	12 to 13 cents.
Hauling to railroad.........	3 to 5 cents.
	17 22

The price per tie delivered along the right of way ranges from 24 to 28 cents. At this price the tie-men are only getting about $8.00 per M. board feet for their lumber, and the owners of the timber only from 50 cents to $1.00 per M. for stumpage. This is too low, and timberland owners should realize that old field pine has a greater value, and is not, as so many people seem to think, a tree of no value or even a hindrance to the development of the country. The waste incident to this industry is very great. In Bulletin 64* of the Forest Service, United States Department of Agriculture, the two methods of tie-making are compared, and its conclusions apply to conditions in southern Mississippi. In the regular tie mills, logs are cut single-tie lengths, and this practice makes the "siding," which is cut off in the manufacture of the ties, so short that there is very little market for it at present. At some mills the best of it is cut off and sold locally at $5.00 per M., but more often it is all thrown away in the slab because there is no market for it even at this low figure. Siding is cut from the best part of the log and ought to make excellent ceiling or sheathing. It should make good boxboard material and could no doubt be used for this purpose if freight rates to the larger markets would justify it. As long as there is this waste, it will probably pay owners of old field pine to hold their timber until better prices are assured and more conservative methods are thereby justified.

Hardwood Logs for Export.—The export of hardwood logs is quite extensive in the Mississippi River counties, where old growth yellow poplar, hickory, ash and white oak are within hauling distance of the railroads. The best

* Loblolly pine in Eastern Texas, with Special Reference to the Production of Railroad Ties, pp 40 and 42..

of this material goes to New Orleans, and is there shipped to Europe for veneer and other purposes. Most of the merchantable hardwoods now left in this region are in the steeper, more inaccessible places. The usual method is to pull the logs to the tops of the small ridges by means of a portable steam skidder or by block and tackle with teams. Wagons then haul the logs directly to the point of railroad shipment. They are now hauled with profit as far as eight or ten miles. At the station the ends of the logs are painted to prevent checking, and the bark peeled from all species but hickory to prevent mildew or other injury to the sapwood. Yellow poplar, ash, hickory and white oak are the chief species exported, though much of the white oak of export quality has been, and still is, taken out for staves. Usually the soil in which the hardwoods grow is suited to agriculture, but the rough character of the ground makes its use for this purpose difficult. When cleared, this land usually washes away rapidly, so that in spite of the good quality of the soil it will in many cases pay better to keep the areas permanently in forest. This should be profitable, because only the larger timber is taken, and fire may easily be prevented. Owners of this land, in selling timber, should stipulate that no young trees of valuable species should be cut, that all unnecessary injury to young timber shall be prevented, and that fires shall be kept out.

Besides large logs, other wood materials for various uses are exported. Dogwood and holly for bobbins, turnery and inlaid work are exported where a sufficient number of cords can be collected in one place to fill a car, for which from $6.00 to $8.00 a cord is obtained at the railroad. Persimmon for reels, bobbins and golf sticks is shipped in small amounts at $5.50 to $6.00 per cord along the Mississippi River, and sassafras for boat construction is frequently shipped to Michigan.

Stave Production.—Stave production has been a large, though scattered, industry for many years. Large quantities of split pipe staves, 5 feet long and over, have been taken out in the past, but the supply of timber suitable for this material is now practically exhausted. At present only the short staves are made, the longest being about 36 inches, and the production of these is constantly diminishing.

White oak is used principally for staves, but red oak is cut out to some extent, especially into oil staves. Willow and cottonwood are occasionally used, although they are too valuable for lumber to warrant their extensive use for this purpose at the present prices. Oak trees fit for staves are very scattered, there being rarely more than one or two per acre, even in good hardwood stands. Much of the timber is defective, and among the trees that are cut only a small part can be actually used, because of knots and blemishes. Most of the staves are produced in Wilkinson and Claiborne Counties; the former furnishes beer staves mainly, which go to New Orleans; the latter whiskey, oil and turpentine staves, which go to Louisville and other Northern and Eastern markets.

Stave mills are portable or semi-portable. In some cases they are set up in the center of a good supply, where they depend largely on farmers to bring them timber in the form of bolts. In other cases, a tract of timber is bought and exploited by the millmen themselves. Stumpage prices vary from $2.00 per cord upward, according to the size and quality of the timber. These prices are equivalent in board measure to from $2.00 to $2.50 per M. For the quality of the timber demanded, this price seems low, although it is doubtful whether the owners at the present time would realize any more for their timber if the logs were sold for export. As timber suitable for staves is nearly always mature or overmature, its removal should beenfit the forest, and this will certainly be the case where the young growth of the valuable species is protected and encouraged. The mature trees of the other species should be disposd of as soon as there is a market for them, otherwise the less valuable species will be favored by a preponderance of seed trees and by a suppression of the most valuable young growth by the old trees.

The future of the stave industry cannot be foretold. The supply of timber of the size and quality now required cannot last very long. White oak grows comparatively slowly, and cannot attain large sizes rapidly enough to make its use for staves alone profitable. There is no doubt, however, that unless substitutes are found, smaller

trees will have to be used in the future. Higher prices will then be paid for stumpage, and white oak will be a most profitable tree to grow.

MANAGEMENT.

The present methods of handling the forest lands of this region are wasteful and destructive, and little or no provision is made for their future care and usefulness. This is especially true of the longleaf pine areas. Township after township has been cut over and burnt until there is practically no pine left standing on the ground, and a useless growth of scrub oak takes the place of valuable pine forest. The only hope for such land is the expensive process of reseeding or planting. The forests that are not already cutover should be so lumbered that the mature timber will be harvested with the least possible waste. The land will then continue to yield the largest amount of timber of the highest value.

Conservative lumbering consists of two fairly distinct operations, namely, the proper selection and complete utilization of the trees cut, and the proper protection and care of those left standing. Conservative lumbering is an investment. A certain amount of timber is left on the ground in order to increase the future value of the property. By leaving from 500 to 1,000 board feet of thrifty, immature trees, and cutting off the mature timber, a stand which is growing rapidly and adding volume at an increasing rate per year is substituted for one which decays as fast as it adds volume, because mature.

Cutting by Types.—The future usefulness of a forest depends in a large measure on the way the present crop of timber is removed. The selection of trees to be reserved to seed up the area, and the reservation of young growths now on the ground to form the basis for the next crop of timber are two of the most important considerations in forest management, and require the exercise of great care and judgment. The selection of seed trees should be made before cutting commences. As these trees are to seed the area after the mature timber has been removed, they should be in such a position that an even reproduction is secured

in the shortest possible time. The number of seed trees needed depends on the size and kind of trees and on the lay of the land. An ideal yellow pine seed tree is a young, barely mature tree with a full pyramidal crown coming well down to the stem, so that there is a large twig surface for seed bearing. It should have a straight, tall trunk, and a strong, well-developed root system, so that it will not be thrown by the wind. Trees 15 to 20 inches in diameter are usually better than larger ones. Trees even smaller can be used for seed, but more of them are required.

Pure Longleaf Type.—It is known from experience that under present methods the longleaf pine forests are not being and cannot be perpetuated. It is also known that under natural conditions these forests have been reproducing themselves up to the present time. It is impossible to lumber a tract and not change the forest conditions in some way. The slighter the change from natural conditions, however, the more likelihood is there of reproducing a forest. The prevention of fires, the exclusion of hogs, and the leaving of seed trees are essential to reproduction, and these things can be brought about if proper precautions are taken. Other influences which probably deter longleaf reproduction are the presence of oak brush, the formation of a dense turf, and the change in the mechanical condition and moisture content of the soil. These influences are not so well understood, and study and experiment will be necessary before their full effects can be determined.

The selection of seed trees and the amount of young growth which should be retained will vary according to the nature of the stand, even within one type. Much of the longleaf pine occurs in pure stands of mature timber with little or no young growth or reproduction. In such stands mature seed trees should be left, but it is a question whether as little timber as possible should be left standing, or whether enough should be left to justify a second lumbering in fifteen or twenty years' time when a good stand of reproduction has been secured. This will depend to a large extent on present and prospective transportation facilities, and on the nature of the stand. Three methods of cutting are here given, all of which can be modified to suit local conditions.

They may be called the selection, the seed tree, and the strip methods.

The Selection Method is most practical on areas where there is any young growth of pine. This contemplates the selection of the mature timber only for cutting. The thrifty, immature timber, often called "sap pine," should not be cut, because it is growing and increasing rapidly in value. The larger sap pines, say from 12 to 15 inches, will be seed trees, and with the smaller ones, will form the basis of a second crop. At least six seed trees should be left to each acre, even if mature trees have to be reserved to make up any deficiency in immature trees. All suppressed, crooked, forked or otherwise defective trees should be cut out with the mature timber, as these are unprofitable trees to leave for future growth. In some cases, however, where there are no better seed trees available, such trees may be left for this purpose. The young timber that is left to grow would, if cut, make lumber of the lower grades and would be the most expensive to log and saw. Therefore, the investment involved in this method is much smaller than one would at first imagine.

In many stands the young growth and the reproduction are chiefly in groups, having come up in openings where trees have died or been thrown by the wind. These groups as a rule, should not be thinned, because in taking out the larger trees from such groups, the faster-growing trees, or those with the greatest promise of future value, are removed, and the suppressed and slow-growing trees are left. If a use can be found for these slow-growing trees some of them may be cut out to advantage, but care should be taken not to open up the groups too much. If the groups consist mostly of small trees, with only a few of the larger sizes scattered here and there, the latter may sometimes be cut out to advantage; the groups would then consist of trees of more even size, and more trees might reach a useful maturity. In such a stand there is need for seed trees scattered well between the groups, as in other variations of this type.

The Seed Tree Method is suited to mature stands of longleaf where there is little or no reproduction or young

growth on the ground. In such cases the sole dependence for the future forest is on the seed trees that are left. These should, therefore, be chosen with great care, Four to six trees per acre should be left, distributed as evenly as possible over the acre. The rest of the timber may be removed.

Seed trees should be sound and healthy, so that in fifteen or twenty years they will have increased instead of depreciated in value, for by that time it will probably pay to lumber the area again for the seed trees. The chief objection to this method is the very serious risk of the seed trees being wind-thrown. Storms are very severe in this region, and when the trees are blown down, there is not only serious loss of timber, but also the only chance of reseeding the ground is gone.

The Strip Method is used to a large extent in Europe and has also been used with modifications in some of our national forests. It seems admirably adapted to certain conditions in the southern pineries, wherever the ground is level enough for a railroad. Especially in mature stands with no young growth, this method could be used to advantage. In such situations it is now customary to locate railroad spurs about 1/8 mile apart and skid the logs in from each side. In the strip method the spurs should be located as they are at present, but the trees should be cut from only half the area, thus leaving strips of forest alternating with the strips of cutover land of equal width. The cutover strips should be logged clean, with the expectation that young growth will start up from seeds from the strips of forest land on either side. When a sufficiently dense stand of reproduction is secured and the young trees have begun to bear seed, in fifteen to twenty-five years' time, the remaining strips should be lumbered in the same way, when the area would in turn be seeded from the young trees. The advantages of this method are: the stand can be cut clean, the trees left in the strips will be less likely to be wind-thrown, and the cost of the second cutting will not exceed the cost of the first. The cost of logging will be lessened, as the logs will be skidded only half the distance, but this may be counterbalanced in certain cases by the increased cost of spur construction per 1,000 feet of timber

logged. The chief objection is that so much timber must be left for the second crop.

Loblolly and Longleaf Subtype.—In this type loblolly pine should be encouraged in every way possible, the object being to substitute this rapid-growing tree for the slower growing longleaf on all suitable areas. Wherever there is any young growth the selection method of cutting should be practiced, leaving all young, rapidly-growing trees on the ground. This is advisable, because young loblolly pine grown in an open stand makes a poor quality of lumber. It produces good lumber only when grown in a dense stand, and it will grow this way only if fire is kept out. Where three or four well-distributed seed trees per acre of loblolly can be secured, no longleaf seed trees need be left. The seeds of the loblolly being much lighter than those of the longleaf, are scattered farther by the wind, and seed years being so much more frequent, fewer seed trees are necessary.

In all types which contain longleaf, considerable foresight is necessary where turpentining is practiced. This operation usually commences three or four years ahead of the lumbering, in order to include the most profitable period for boxing the trees. Trees necessary for seed trees and all second growth that is to be left should be selected before turpentining begins, or else a diameter limit should be set large enough to include the trees to be saved. These trees should not be boxed or tapped for turpentine, for otherwise their value will be impaired. It is best to mark the trees to be removed in the lumbering which will follow, and allow only the trees so marked to be boxed.

Longleaf Hills Type.—In this type there is the same necessity and perhaps a greater opportunity for conservative management of forests than in any other. Considerable areas of the type are still in an almost virgin state, and owing to the steepness of the hills and the consequent danger from erosion, and the general unsuitability of much of the soil for agricultural purposes, they should be kept in a thrifty and profitable forest growth. The three commercial yellow pines—longleaf, shortleaf and loblolly—grow well, and reproduction, especially of shortleaf and loblolly,

is assured if fire is kept out and proper provision made for seed trees. The chief aim should be to reproduce a mixture of loblolly and shortleaf, with a preference to the former because of its more rapid growth. The longleaf is a poorer seeder, grows more slowly, and seems to be gradually giving way to its more vigorous competitors. In the hardwood hollows loblolly usually reproduces successfully. The more valuable hardwoods, as yellow poplar, ash and hickory, should be favored against all other trees but loblolly pine by leaving seed trees and protecting the young growth.

Young growth of pine is much more frequent in these hills than it is over most of the pure longleaf area, and so the selection method of cutting, already described, should be practiced in most cases. As much immature pine as possible should be left on the ground, in order that it may have the advantage in the struggle with the poorer species of hardwood. In selecting seed trees, shortleaf should be preferred to longleaf, since it grows faster and forms denser stands. Loblolly, however, in all situations favorable to its growth, is a more desirable tree than either. Young growth of all species should be left, not only to form the basis of a second crop, but to prevent erosion.

Hardwood Hills Type.—A considerable part of this type is still in the forest, and on account of the steepness and general unsuitability of much of it for cultivation, it should be used permanently for the growth of trees. Of course, with improved methods of farming and a denser population more land will be cleared and cultivated, but in all agricultural regions at least a part of the land should be used for the production of cordwood, posts, poles and lumber for local needs. The steep hillsides and narrow ravines found throughout this type are better adapted to this purpose than to any other. The deep, fine, silty soil begins to wash badly as soon as cultivation is attempted, and under ordinary circumstances the steep slopes have to be abandoned in a very few years. A mixed growth, usually of very inferior quality, gradually takes possession of these areas, but the erosion goes on until the under clay is reached, often 50 to 100 feet below. Such land should never be cleared, but should be kept in a thrifty growth of timber, and made to

yield, by wise management, the greatest possible returns as a long time investment. The soil being rich and the moisture conditions generally good, tree growth is rapid, and where the better species are encouraged, the owner might expect returns in a comparativly short period.

In cutting these mixed stands of trees of all ages the selection system is by far the most practical. The old, mature and overmature trees should be removed, leaving the young, thrifty, immature saplings and poles with plenty of room to grow and develop. If possible, the less valuable species should be removed with the better kinds, for otherwise the quality of the forest will have a tendency to deteriorate. Seed trees of yellow poplar, ash, walnut, hickory and white oak should be saved wherever there are not sufficient young trees of these species to secure a second growth. If these seed trees are retained, with proper care, each succeeding crop of timber will consist of a larger proportion of desirable kinds. The present method of cutting for export leaves practically all the small and immature timber, and where an adequate supply of seed trees is also included, the forest is left in very good condition.

The number of seed trees which should be left to the acre will vary according to the topography, the stand, and the species. Naturally, seed will scatter farther from a tree on the top of a ridge than from one in a hollow. Fewer seed trees will be needed where there is plenty of young growth. Trees with light or winged seed, such as ash, yellow poplar and sycamore, will scatter their seed farther than the heavy seeded oaks and hickories, and consequently fewer seed trees per acre will be necessary. Two or three seed trees per acre of poplar or ash are sufficient, while walnut, hickory or white oak will require more. It is not recommended that all the seed trees be of one species; but a variety of the best species should be retained in order to maintain the mixed character of the forest.

Old fields, grown up to loblolly and shortleaf, are a more important part of this type than of any other, owing to its older settlement and larger percentage of cultivated land, though these old fields are a common subtype of forest all over the region. Many areas that were regularly cultivated

up to the time of the war, and which have grown up to pine since, are now being cut over for ties.

Where ties are hewn it is often the practice to cut only the larger trees, and so enough small ones are left to form a second crop and seed up the openings. This is the best way to cut this second growth pine, and even where a sawmill is employed, the smaller trees can be left with profit, unless the owner means to clear the land and put it in cultivation. In cutting pine, loblolly should be favored at the expense of the shortleaf, because of its more rapid growth.

Many old fields, especially in the western part of the region, grow up to hardwoods only, because there are no seed trees of pine in the neighborhood. The better species are generally scattered, but should be encouraged. Where an occasional loblolly pine occurs, it should be left to grow to help seed up this area. Sometimes black locust comes in on abandoned areas, and it is probably the most profitable tree to grow on old fields where the soil is rich and deep. It grows rapidly and is in great demand for fence posts. After cutting, locust reproduces itself rapidly by means of suckers or sprouts from the roots, which come up for considerable distances around the stump. For this reason, cutting may begin with advantage just as soon as there are any trees large enough to make posts. Increased cutting tends to increase the density of the stand. Trees should be cut during the winter or early spring if possible, and never in late summer or early fall, as early frosts will kill the shoots and prevent reproduction. Fire is exceedingly destructive to black locust and should be kept out by all means.

Mississippi Flood Plain.—These lands are too valuable to remain permanently in forest. Much of the level land along the banks of the Mississippi River and formerly occupied by stands of cottonwood has already been cleared and is extremely valuable for agriculture. Movements are on foot to deepen the channels of the streams, clear them of underbrush and drain large areas of land which will then become productive. Lumber companies are cutting away the cottonwood and other timbers along the Mississippi River and

extending dummy lines into the Homochitto swamp region. When the valuable timber is gone, a parge per cent of the swamp areas will gradually be transformed into prosperous plantations.

But for a long time to come there will be considerable land on nearly every plantation that cannot be profitably cultivated, because it is too difficult to drain, overflows too easily, or else the owner has all the cleared land he can cultivate with the labor available. This woodland should be managed with as much forethought as any other part of the plantation.

The same methods of cutting should be used as in the hardwood hills type. The retention of the young immature growth, especially of the valuable species, and the leaving of seed trees where necessary should form the basis of management in nearly all parts of this type. Ash, oaks, pecan, cypress and sweet gum should be encouraged wherever conditions are suitable for their growth.

On this type the lighter seeds are usually carried by the overflow waters, so that the leaving of seed trees of cottonwood, willow or sycamore is quite unnecessary. Oaks, hickories and ash should be left for seed trees where these species are desirable. Plenty of young growth should be left to form at least a partial shade, or the weeds and vines are likely to grow so rank and dense after the timber has been removed that they prevent reproduction.

Young stands of pure cottonwood, however, seem to demand a different treatment. As far as can be determined, no old stand is ever reseeded to cottonwood, unless from overflow. Seed trees, therefore, are useless. Again, as cottonwood stands are nearly all even-aged, the smaller trees, with scarcely an exception, are badly suppressed and are not worth saving for a future crop. In older stands, however, there is usually a second growth of sycamore, elm, oak and mulberry, which should be protected unless the land is to be cleared for agriculture. Young cottonwood stands, if a market can be found for cordwood, should be thinned by taking out the smaller trees, thus utilizing them before they die, and also giving room for the larger trees to develop rapidly into more merchantable saw-timber.

River and Creek Bottoms.—Much of this type has been cleared and cultivated for many years, and practically all of it will be cleared for agriculture within a few decades, or as soon as the difficulties of drainage have been overcome. In the meantime, however, the forests which are growing on these lands should be cared for and made to yield the greatest possible revenue. Although many years may pass before the land is cleared for farms, it is doubtful economy to grow new forests or consider the present forests permanent. It is desirable to make the most of the growth that is already on the ground.

The selection method of cutting should be followed here as in the other hardwood types, leaving as much young growth as possible on the ground and taking out the mature timber. What is cut should be used to the best advantage, and the woods left in such condition that the remaining trees will make the best timber in the shortest possible time. Care should be taken to protect the young growth, especially that of the more valuable species, and to see that trees are not unnecessarily felled on promising young trees when cutting is being carried on.

*Waste in Logging.**—Waste of timber in logging is attributable to many causes, probably the chief of which are the distances from market, labor conditions and methods of purchase. Much waste is unavoidable under present conditions, but where it can be avoided, every care should be taken to do so.

Waste in logging is of two kinds: (1) the incomplete utilization of the trees cut, and (2) the injury and destruction of reproduction and trees that are left.

(1) The cutting of high stumps is a common and very wasteful practice, and is inexcusable except where trees are badly burnt or rotten at the butt. Stumps in the average pine forest could be cut down to 12 or 15 inches, and should rarely be over 18 inches high.

Much merchantable timber was formerly left in the tops, but owing to better market conditions this waste is becom-

* See also extract No. 398 from the Yearbook of the U. S. Department of Agriculture for 1905, entitled "Waste in Logging Southern Yellow Pine," which can be had on application to the Forest Service.

ing less each year. However, young thrifty trees which should be left to grow are being cut down for cross-ties, while knotty logs capable of making excellent ties are left to rot in the woods.

In many small operations, especially where ties are being cut from old field pine, there is considerable waste in the slab. Instead of getting, as in the hardwood regions farther north, an average of 10 board feet of siding per tie, which is usually cut from the best part of the log, all this is often left in the slab and wasted. The absurd conditions of the market, which have placed a ban on 8-foot lumber, are responsible for this waste. There will undoubtedly be a modification in the market requirements within a few years, and timber owners will do well to hold their pine rather than sacrifice it as they are doing now. In selling standard timber, small owners should insist on the least possible amount of waste, not only when they are selling their timber by the thousand board feet, but even when they are selling by the acre or by the boundary.

(2) In the average logging operation tremendous injury is done to the trees left standing and to the reproduction already started. Every care should be taken to avoid this as much as possible. Trees should be felled in such a way that the young trees are not broken or crushed, or groups of young growth destroyed. If the breaking of some young trees is unavoidable, those of greatest value should be saved. Inasmuch as immature trees increase in value with age, a group of longleaf thirty years old, for example, should be preserved in preference to one only ten years old. Also, where a choice is necessary, a tree should be felled into a young gum or beech rather than into a thrifty ash or yellow poplar. Trees should be felled so that the tops, though left to lie where felled, will not subsequently be a menace from fire to the remaining stand; that is, they should be as far away from seed trees or groups of young growth as possible. Where a steam skidder is used, it should be placed in such a position that the logs will be pulled over ground which has comparatively little young growth. Guy chains for the skidding cable should be fastened to stumps and not to seed trees or young growth.

*Fire Protection.**—Conservative lumbering counts for little unless the forest lands of the State can be protected from fire. After lumbering in the longleaf pine forests, the ground is partly covered with brush, which soon becomes so dry that fires are easily started and are extinguished with great difficulty. Logging locomotives are largely responsible for the first fire that follows lumbering. Every year following, however, the ground is burned either through malice or through the notion that it encourages a better growth of grass. Pine reproduction is not given a chance, even though much of the stump land region has enough trees remaining to seed up the ground. Scrub oaks, more resistant to fire, form dense stands over the stump lands. The absence of pine reproduction is largely due to this constant burning of the area, although other factors also enter into the problem.

Reproduction of loblolly pine is so much more prolific and certain than that of longleaf that damage by fire is not felt so seriously with this tree. However, the growth is retarded and the quality of the timber decreased by constant burning of the ground. Hardwood lands suffer in the same way by injury to reproduction, sprouts and young growth where fires are permitted to run.

Protection from fire is necessary at all times, but especially during and immediately following lumbering operations. The large amount of inflammable material, added to the ground cover by the slash, makes the fires much more severe and seriously endangers the seed trees and young growth left on the ground. Brush should be cleared away around all steam skidders and other engines and should not be left near seed trees or other young growth. Logging hands should be cautioned against throwing matches or cigarette stumps around in the dry grass or leaves. It should be generally understood that any man, and all men if necessary, employed on the operations are expected to stop work at any time in order to extinguish fires. After logging, fire can only be kept from the large pine tracts by a

* NOTE. The prevalence of forest fires and the destruction caused by them through the longleaf pine region is dealt with in Forest Service Circular 149, "Condition of Cut Over Longleaf Pine Lands in Mississippi."

system of patrol, or by the aid of a good State law. Probably some patrol would be needed for a while, even though a State fire law were enacted. A fire line around a tract or on each side of a railroad running through the tract is a great aid in preventing or extinguishing fires. Such a fire line is best made in the pure longleaf by plowing two strips 3 or 4 feet wide and 30 feet apart, and then burning off the middle strip of unplowed ground every winter.

It is much easier and cheaper to prevent fires than to extinguish them after they are well started. Patrol during a very dry period or through the dangeous months will practically prevent serious fires and will cost less than extinguishing one big fire. A scheme of co-operation between the large timber owners and the county, if it could be arranged, would prove a cheap and most satisfactory way to handle this important problem.

Injury from fire is not so serious in the hardwood types of this region as in the pine types, though much damage is done every year. There is no sentiment against setting fire to the woods or old fields, and the landowners realize that it is a most difficult and nearly impossible task to prevent it. For the present, undoubtedly the best remedy is to create a good, healthy sentiment against fires.

Protection from Stock.—Fire, although the chief danger, is not the only serious menace to the forest. The ranging of stock, especially of hogs, does great injury in some places.

The question of restricting the right to graze animals in the open woods is usually one that solves itself with the increase in populaion and the general development of a region. Settled communities demand that animals shall be enclosed.

Throughout the woodland region of Mississippi, however, it does not yet seem necessary for farmers to keep their cattle under fence. It would work a hardship on small owners if their cattle could not graze at large, and no law to prevent them from making use of the splendid growth of grass in the woods is yet needed. Cattle do comparatively little injury to pine reproduction, and throughout the hardwood region they are usually kept within fences.

When hogs range over the woods in large numbers they destroy considerable seed of different species, greatly hindering reproduction. Where pine seed trees are scattered and seed is only produced abundantly once in four to eight years, which is the case with longleaf pine, it is readily seen that hogs, always on the lookout for pine nuts, will seldom give them a chance to germinate. Also, as food becomes scarce late in the winter, hogs dig up and eat the roots of the young pines. No hardship would be inflicted by compelling owners to fence their hogs, but rather a real benefit to the farmer as well as to the timberland owner would result. In some parts of the yellow pine region hogs are not listed for taxes, because they are considered as practically valueless property. Large numbers of them are swept away by disease each year, and it is only in good seed years that there is mast enough to fatten them. By taking the hogs off the range, infectious diseases would be stamped out in a very short time, and the grade of stock would gradually improve. The State should pass a law compelling the fencing of hogs. If it fails to do so, each longleaf pine county should take advantage of the present local option law, which allows counties and districts to regulate this question, and prevent the promiscuous grazing of hogs through the woods and cutover lands.

Contract for Sale of Timber.—Small private owners, trustees of school lands, and others who sell standing timber for removal, should insist on the adoption of all practicable precautions to insure the future usefulness of the area. In a contract for the sale of timber, the following recommendations and clauses are suggested:

1. Describe the sale area by legal subdivisions; metes and bounds, or by a designated name.

2. Estimate the amount of material, preferably by species, included in the sale.

3. Specify whether full or partial payments will be made.

4. No timber will be cut or removed until it has been paid for.

5. No timber will be removed until it has been scaled, measured or counted.

6. All merchantable timber used in buildings, skidways, bridges, construction of roads, or other improvements will be paid for at the contract price, but no charge will be made for material not merchantable under the terms of this agreement and not reserved for seed.

7. All cutting will be done with a saw when possible.

8. No unnecessary damage will be done to young growth or to trees left standing, and no trees shall be left lodged in the process of felling.

9. No trees shall be turpentined unless they are to be cut subsequently.

10. The approximate minimum diameter limit at a point 4½ feet from the ground to which living trees are to be cut is ...., but trees above these
(Limits for all species involved)
diameters may be reserved for seed or protection. A good diameter limit at 4½ feet from the ground is 15 inches, and in no case should it be below 12 inches.

11. Stumps will not be cut higher than .... inches—lower when possible—and will be so cut as to cause the least possible waste.

12. All trees cut will be utilized to a diameter of ....inches in the tops—lower when possible and the log lengths so varied as to make this possible.

13. All timber will be cut and removed on or before and none later than ...., and at least ....
(feet, b. m. cords, etc.)
will be paid for, cut and removed on or before ....
19.., and at least .... of the remainder of the estimated amount during each year of the remaining period.

14. Timber will be scaled by the .... rule, or counted, or measured as follows: ....
....

15. During the time that this agreement remains in force, ... and all .... em-
(I or we) (my or our)
ployees, subcontractors, and employees of subcontractors will do all in our power to prevent and suppress fires upon this sale area.

16. A bond for fulfillment of contract should be required in the amount of 10 per cent of the purchase price.

RECOMMENDATIONS.

In Forest Service Circular 149, "Condition of Cutover Longleaf Pine Lands in Mississippi," suggestions are made for a forest, and fire law for the State. This circular recommends the appointment of a State fire warden, with local fire wardens in each county to carry out the provisions of the law, and the acquisition and administration of lands by the State forest use. In addition to these recommendations, which were preliminary, it is now strongly recommended that the State or counties extend the operation of the stock law, and that the timbered school lands, which are controlled by the various counties, be managed according to forestry principles.

State Forester.—Undoubtedly all the States whose forests form a large part of their resources, which is the case with Mississippi, should employ technically trained foresters to care for these forests. The work of a State Forester is most effective, where he is absolutely free from political influence, thus making his tenure of office entirely dependent on his fitness for the position and the quality of the results obtained. He should be the State Forest Fire Warden, directing the fire-fighting force of the State, and he should manage and administer any State forest land that may be acquired under the law, and conduct experiments in management and reforestation. He should make examinations of private forest lands, if the owners so desire, and give suggestions for their better care and management. He should carry on an educational campaign throughout the State, giving lectures at farmers' institutes and other public meetings. By such lectures he would be brought into close touch with the people of the State, who should be urged to

perpetuate by wise use the forests on all lands not needed for agriculture.

Fire Law.—The fire law as outlined in Circular 149 should be carried out and enforced by the county fire wardens, under the direction of the State Forester and the Board of Forestry. These local officers should be appointed by the county Board of Supervisors with the approval of the State Forester and should be paid out of the county funds. Their remuneration at $2.00 a day, for all days actually engaged in extinguishing fires or prosecuting offenders, should not exceed $200.00 per year, and the expenses of extra help to fight fire might vary from $100.00 to $200.00 more. The counties themselves depend so largely on the timber lands and timber interests for revenue, that money spent for the protection of the forests will be an excellent investment.

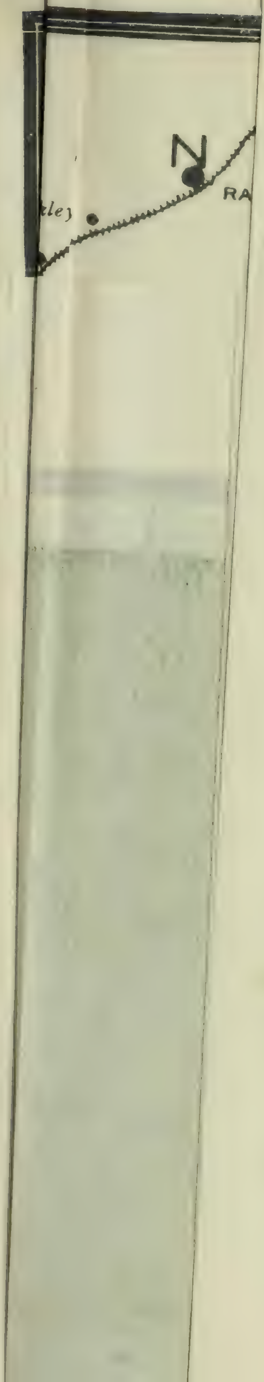
State Forests.—Forest lands, properly managed, are among the most profitable investments carried by many of the European States. In this country several of the States have adopted the policy of acquiring and administering forest land. The chief value of State forests are (1) to protect the headwaters and the banks of important streams; (2) to furnish a reserve source of timber or fuel supply for the citizens of the State; (3) to serve as object lessons of practical methods of forest management and forest regeneration. Lands for this purpose may be obtained by purchase or by forfeiture. Some States provide that land reverting to the State for taxes shall, if suitable, be held for forest purposes. It is strongly recommended that this be done in Mississippi. From time to time, land in almost every county reverts to the State for taxes. Such tax land is recorded in the books of the State Land Commissioner at Jackson. After two years it may be sold by the sheriffs of the respective counties. Before being put up for sale a list of the tracts of such land should be submitted to the State Forester, who should, if the location and amount justify, examine them and report to the State Board of Forestry as to their suitability for State forest purposes. If more suitable for agricultural purposes, they should be put up for sale, but if not, they should be retained by the State

for forest purposes. Tax land sells for about $1.25 per acre. Usually the timber has been cut off, and the land is seldom very desirable for agricultural purposes. Under State ownership and protection these lands should constantly increase in value and produce timber crops for the benefit of future generations. They should be forever held by the State and so distributed as not to be a burden upon any one county.

School Lands.—The sixteenth section in each township was originally given by the Federal Government to the State, to be held by it as a source of perpetual revenue for the benefit of the public schools of the county in which the section is situated. These school sections are controlled and administered by the local authorities, and all revenues are devoted to the schools of the township or districts in which the sections lie. They can be divided into two classes: (1) Those that have been disposed of on long term leases, or (2) those that are under the direct control of the county.

During the middle of the last century many of these sections were leased for ninety-nine years or other long periods. As a rule the leases are now held by lumbermen who have either cut off the timber, or intend to do so. When cutover the land is neglected, and when the leases expire, a large part of the land will come back to the State without any possibility of its yielding an income to the schools for an indefinite time. In the future, therefore, in lumbering the school lands, the State should insist that they be kept in a productive condition, so that the object of the lands, to provide a revenue for the schools, is not defeated. This can be accomplished by imposing certain restrictions on the cutting, such as are outlined under the chapter on "Management."

The school sections which have not been leased for long periods are controlled by the township trustees and the County Superintendent of Education. They should either be leased for agricultural purposes at an annual rental, or if timbered, the standing timber should be sold and removed. When a sale of timber is made, a contract should be entered into with the purchaser similar to that previously suggested, in order to prevent the destruction of young growth and preserve the yielding power of the forest.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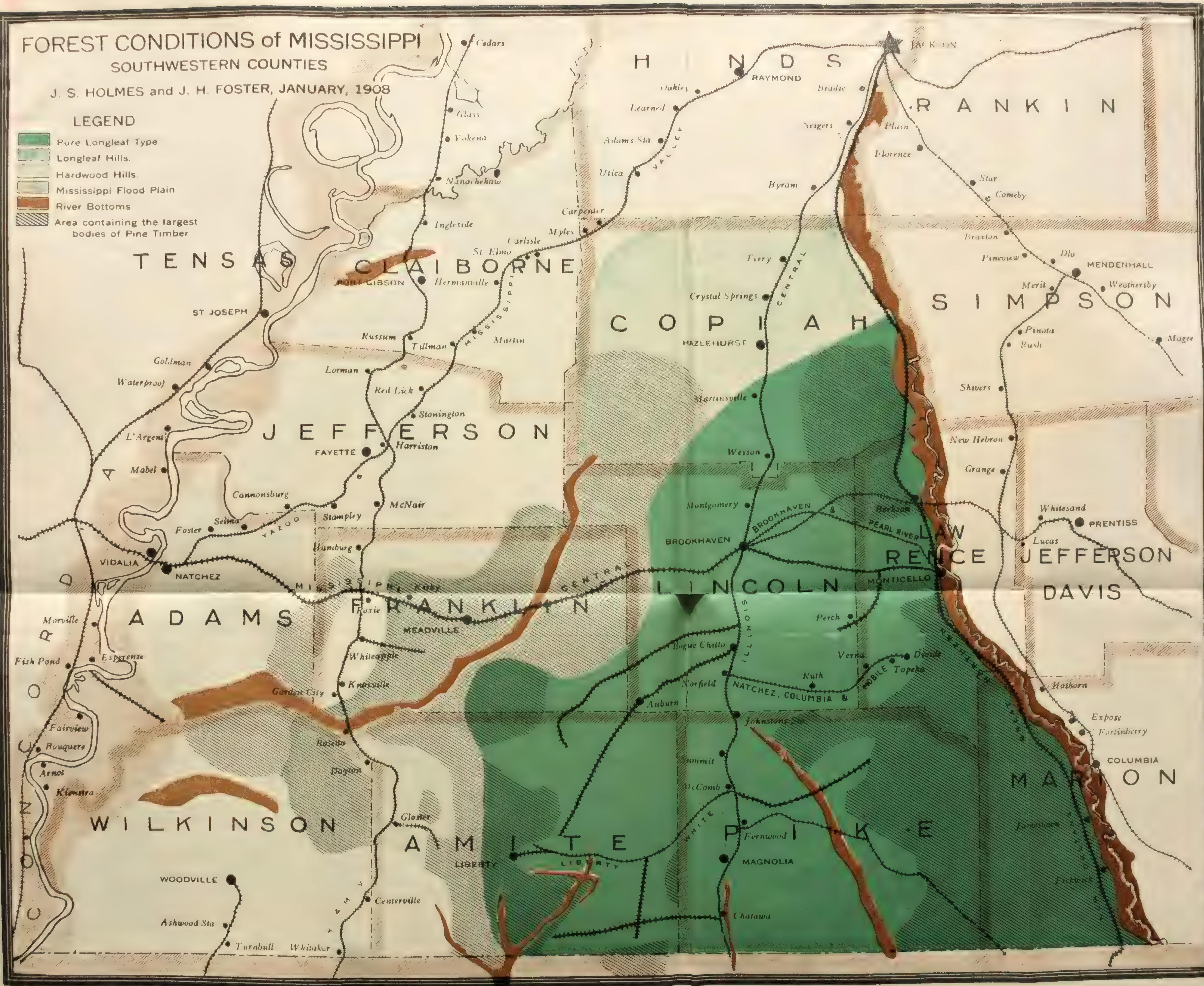

FOREST CONDITIONS of MISSISSIPPI
SOUTHWESTERN COUNTIES
J. S. HOLMES and J. H. FOSTER, JANUARY, 1908
LEGEND
Pure Longleaf Type
Longleaf Hills.
Hardwood Hills.
Mississippi Flood Plain
River Bottoms
Area containing the largest bodies of Pine Timber
HINDS
RANKIN
TENSAS
CLAIBORNE
COPIAH
SIMPSON
JEFFERSON
LINCOLN
LAWRENCE
JEFFERSON DAVIS
ADAMS
FRANKLIN
WILKINSON
AMITE
PIKE
MARION
CONCORDIA
JACKSON
RAYMOND
PORT GIBSON
ST JOSEPH
HAZLEHURST
FAYETTE
MENDENHALL
BROOKHAVEN
MONTICELLO
PRENTISS
VIDALIA
NATCHEZ
MEADVILLE
COLUMBIA
LIBERTY
MAGNOLIA
WOODVILLE
Cedars
Glass
Yokena
Nanachehaw
Ingleside
Oakley
Learned
Adams Sta
Utica
Bradie
Seigers
Plain
Florence
Byram
Star
Comeby
Carpenter
Myles
Carlisle
St Elmo
Hermanville
Martin
Russum
Tillman
Lorman
Red Lick
Stonington
Harriston
McNair
Goldman
Waterproof
L'Argent
Mabel
Cannonsburg
Selma
Foster
Stampley
Hamburg
Terry
Crystal Springs
Martinsville
Wesson
Montgomery
Braxton
Pineview
Dlo
Merit
Weathersby
Pinola
Bush
Magee
Shivers
New Hebron
Grange
Whitesand
Lucas
Perch
Bogue Chitto
Verna
Divide
Topeka
Ruth
Norfield
Auburn
Johnstons Sta
Summit
McComb
Fernwood
Chatawa
Hathorn
Expose
Fortinberry
Morville
Fish Pond
Esperanza
Whiteapple
Knoxville
Garden City
Roxie
Rosetta
Dayton
Gloster
Centerville
Fairview
Bouquero
Arnot
Kienstra
Ashwood Sta
Turnbull
Whitaker
VALLEY
MISSISSIPPI CENTRAL
YAZOO
ILLINOIS CENTRAL
NATCHEZ, COLUMBIA & MOBILE
BROOKHAVEN & PEARL RIVER

Mississippi State Geological Survey

E. N. LOWE, DIRECTOR.

BULLETIN No. 5

A STUDY OF

FOREST CONDITIONS

OF

Southwestern Mississippi

BY

J. S. HOLMES, Forest Examiner
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BRANDON-NASHVILLE